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WATER REQUIREMENT AND ADAPTATION IN EQUISETUM

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I. INTRODUCTION

A study of the water relations of *Equisetum* was undertaken to throw light upon the nature of bog xerophytes and the successional relations of *Equisetum* in the hydrosere and paleosere.

The functional responses of a plant to the water content of its habitat determine the xerophily of the plant. Usually the impress of an extreme habitat is recognizable at once in the structure of the plant. This, however, is not always the case. In the group of plants known as bog xerophytes many of the members, while superficially exhibiting xerophytic structures, also show characteristics of hydrophytes, namely, large airspaces and diaphragms. Moreover, these plants grow in the same habitat with true hydrophytes such as *Sagittaria*, *Ranunculus*, and *Caltha* (Clements 1907: 168). While the nature of the habitat has been subjected to much investigation, very little inquiry has been made as to the nature of the plants themselves. The purpose of this experimental study of the water requirements and adaptations of *Equisetum* was to determine whether this plant is a xerophyte as has been supposed, or whether it is truly a hydrophyte as its habitat suggests.

The problem was suggested by Dr. F. E. Clements and the work was carried on under his direction. The writer gratefully acknowledges her indebtedness for the many helpful suggestions in carrying out the work. Acknowledgments are also offered Miss Frances Long for the determinations of photosynthate and to Mr. Gorm Loftfield for the night readings on the position of the stomata.

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SUMMARY OF VIEWS AS TO BOG XEROPHYTES

1. Much emphasis has been placed upon the physiological aridity of bog habitats and its causes, but as yet an adequate explanation has not been found. It is generally believed that the water available for plant use is limited in certain zones (Burns 1911: 106) characterized by xeromorphic plants. Clements (1916: 90), however, questions the theory of physiological drought, while Cates (1914: 455) has shown that winter is the deciding factor in the xerophily of the most typical of the bog plants, namely the evergreen heaths.

Schimper (1899: 6) pointed out the difference between physical and physiological dryness. The latter is attributed to high concentrations of salt and humous acids in the water (1898: 691). This suggested to Livingston "that if the physiological dryness of the bog be due to humous acids or humous salts, these substances may check the absorption of water by plants either physically by high osmotic pressure or chemically by toxic or stimulation effects" (1904: 383). He therefore made a study of the osmotic pressure of a series of bog waters. He found practically no difference in the osmotic pressures, and concluded that bog waters do not have an appreciably higher concentration of dissolved substances than do the streams and lakes of the same region.

Livingston (1905: 348) later made an investigation of the physiological properties of bog waters by growing an alga (*Stigeoclonium*) in them and found that "many bog waters act upon the plant like poisoned solutions." He says, "The stimulating substances are most markedly present in water from those swamps whose vegetation is most definitely of the bog type. They are absent from river-swamps and large lakes; in water from swamps whose vegetation is of a character intermediate between those of the river swamp and the bog, they are present to some degree, their amount being roughly proportional to the extent of the xerophilous character of the vegetation."

Dachnowski (1910: 339) has extended the toxic theory. From a study of physiological aridity, he concludes that "the real

determining factor in the bog habitat is the ratio of the possible rate of water absorption to the rate of transpiration, and that the toxicity of the bog habitat has a primary rôle in bringing about bog conditions." From his study of cultures of isolated bog bacteria he concludes that bacterial toxins are the leading factor to be considered in the physiological aridity of bogs.

Rigg, (1913: 310) from his investigation of the effect of bog waters on the root-hairs of *Tradescantia*, suggests that "the toxins act through their stunting effect on root-hairs." In other words, plants which grow in bogs can have only a low absorptive power.

The conclusion of these writers is that the xerophily of bog plants is due to the toxic effect of the habitat.

(2) *Xerophytic nature due to persistence of stable structures*

Clements (1905: 126) holds the view that many of the so-called swamp xerophytes are not xerophytes at all, but are plants which have developed their xerophytic features while growing on dry land. They have subsequently been able to adjust themselves to present conditions without undergoing a corresponding change in structure. His view is based upon the presence of hydrophytic structures in the plants and the association of the plants with typical hydrophytes.

(3) *Winter xerophily among plants*

Gates (1914: 445) has made a very thorough study of the nature of the evergreen heaths growing in bogs, principally *Chamædaphne*, and concludes that "in view of the fact that exposure to the very extreme summer conditions in 1911 and 1912 did not affect the vitality of the evergreen ericads, that neither did the average winter of 1910–1911, with its scanty snow covering during the coldest weather, while the extreme winter of 1911–1912 killed the parts of the evergreen ericads which projected above the snow; and in view of the fact that the evergreen habit is hereditary, that the position of the leaves in winter is different from that in summer, and that the trans-

piration is decidedly less than that of deciduous shrubs and of herbaceous plants in summer, but greater in winter, the xeromorphy of these plants is real xerophyty, occasioned fundamentally by the necessity of protection when exposed to winter conditions and used advantageously by these plants during the summer.

2. Successional Relations of Equisetum

(1) *In the Hydrosere*

Equisetum is found in such a wide range of places that its natural position in the development of vegetation is somewhat puzzling. From Clements (1916: 184–278) summary of climax formations we find that Shaffner, Jennings, and Tyler in their description of the concentric zones about Brush Lake in Ohio found *Equisetum fluviatile* in the swamp zone along with *Carex* and *Scirpus*. Cowles in sketching the general course of succession on rock hills, sand hills, clay hills, and lake bluffs found the secondary succession on the lake bluff beginning with xerophytic herbs such as *Melilotus*, *Aster*, *Equisetum*, and various grasses. Resoll found a pool which in 1898 contained little but *Sparganium minimum* a dense mass of *Equisetum fluviatile* in 1912. Burns (1911: 106) in his description of the distribution and position of zones in the bogs of southern Michigan gives *Equisetum fluviatile* as a member of the floating sedge zone. This together with the two succeeding zones, bog and tamarack, is called the xerophytic region of the habitat. Bergman and Stallard (1916: 339) reported *Equisetum fluviatile* often occurring as a socies in the *Scirpus-Zizania* associes. "In places it forms rather extensive areas of pure growth, notably on Leech Lake near the mouth of Boy river and at the west end of Long Lake near Ely. Usually, however, *Equisetum* occurs mixed with other species of the associes." It is also reported among the plants often occurring in small numbers in the *Carex* associes.

(2) *In the Paleosere*

Equisetums reached their most luxuriant growth during the Pennsylvanian Period of the Carboniferous Age. The *Calamites*, great tree-like equisetums one to two feet in diameter and often sixty to ninety feet in height, are reported by Grand Eury to have formed great forests in Central France. According to Chamberlin they probably frequented swamps and lowlands. The evidence of the present day water relations of *Equisetum* substantiates the view of Clements (1916: 421) that the reed swamp associes of today was probably represented by the smaller *Calamites* in the paleosere.

(3) *The climate of the Carboniferous age*

The following, from Chamberlin and Salisbury, is a summary of the plant life of the Pennsylvanian Period and the inference as to climate. The Coal Flora was made up of the following groups of plants: Filicales, Cycadofilices, Equisetales, Sphenophyllales and Lycopodiales. Equisetales were represented by Calamites, whose branches and leaves were arranged in whorls. The leaves were much reduced in size but not so much so as in the present day forms. "The structure was of the type adapted to dry weather as in the pine and many desert plants, and also, strangely enough, in undrained swamp plants. They (Calamites) probably frequented swamps and lowlands." The opinion of some geologists is that the climate of this period was more or less dry and cold. Their judgment is based on the xerophytic nature of the dominant plants, the lepidodendrous, sigillarias, calamites, and cordaites.

"The force of the inference from the xerophytic aspect of the overgrowth is much weakened, however, by the fact that the vegetation of undrained swamps and bogs assumes many of these xerophytic features, which in such cases, obviously become pseudoxerophytic. A satisfactory explanation of this phenomenon has not yet been found, nor has its extent and its limitations, either in respect to the nature and degree of swampiness neces-

sary to produce it, or in respect to the kind of plants or plant parts affected, been so thoroughly worked out as to permit a close application to the problem in hand. It is obvious that to fit the case, marsh or bog conditions must have produced pseudoxerophytic adaptations in the great mass of the tree growth, but not in ferns and spenophyllous plants. The effects must apparently also be extended to all plants brought into the depositing basins by drainage, whether these were true swamp plants or not, unless a closer study of the coal flora shall show that the xerophytic aspect was not assumed by all species of the trees involved. It is clear that a more critical study of the problem on all sides is necessary before a final conclusion can be reached."

Dachnowski (1912: 278) questions this theory on the ground that the plants encountered adversities of soil-water content rather than of climate.

II. METHODS

The general plan followed was to make a quantitative comparison of the water used by *Equisetum* and that used by certain other plants of well known habits. The latter include *Bryophyllum calycinum*, a xerophyte, *Helianthus annuus* and *Phaseolus vulgaris*, mesophytes, and *Ranunculus sceleratus*, an amphibious hydrophyte. Under the term "water requirements" the water used in various ways by the plant is included, the purpose being to determine whether in its physiological processes *Equisetum* uses more or less water than the other plants.

(1) SOURCE OF PLANTS

In the spring of 1916 attempts were made to transplant the fertile stems of *Equisetum arvense* into glazed pots in order to compare their rates of transpiration. No matter how carefully the plants were taken up or how little the soil was disturbed, they wilted almost as soon as they were put in the greenhouse. This may be accounted for by the fact that the rootstocks of this species grow very deep into the ground and it was always

necessary to cut the underground stems. In a few cases dormant buds on the plants transferred developed into plants of moderate size. This suggested that it would be necessary to dig up the stems before the spring growth started, but by this time it was too late to find any more buds.

Early in June similar attempts were made to transplant *Equisetum hyemale* with similar results. In one case a block of soil twelve inches in diameter and eighteen inches deep was cut out and carefully lifted into a large jar. This was done on a rainy day when conditions were ideal for transplanting, but by the next day the plants were wilted. A trench was then dug in order to trace the root systems. Underground stems were frequent at a depth of two feet, although most of them were in the first twelve to fifteen inches of soil. Roots were traced to a depth of three feet and one inch from which point they were submerged in the water of an underground spring.

Potometers with cut stems of *Equisetum hyemale* were then tried but, although there were no signs of wilting, the rate of transpiration decreased so rapidly and steadily that this method was discarded as unreliable. The only possible solution seemed to be to get the buds on the underground stems during their resting period.

During October and November large clumps of earth matted together with the root stocks of *Equisetum fluviatile* were dug from the edge of a tamarack swamp near Glenwood Park, Minneapolis and brought to the greenhouse. Profiting by past experiences, pieces of soil were cut to just fit into their pots but it was soon found that too much competition between the many *Equisetum* stems and other plants in the soil was hindering good growth. Other *Equisetum* buds were then carefully separated from the soil in which they had grown and planted in porous pots containing ordinary garden loam. The stems began coming up at once and very good plants developed in the course of six weeks. Some of the material brought in from the swamp was covered with a sack and left out in the yard all winter. In March, when the frost was beginning to leave the ground, these were brought in and planted in loam just as the others had been.

In some cases these spring plants grew almost to the full size attained in the field.

During the latter part of October some *Equisetum hyemale* was found growing in the glen along the Mississippi river at Fort Snelling, Minnesota. These plants were growing on the side of a hill in deep shade. The root systems proved to be rather shallow and when the plants were transferred to the greenhouse only a few of the stems turned yellow. Throughout the winter abundant new shoots developed while most of the old stems died down towards January. *Equisetum arvense* was dug early in April. *Ranunculus sceleratus* was grown from seedlings, which Mr. Folsom of the Botanical Department of the University had grown in mud for a number of generations. The plants of *Bryophyllum calycinum* were cuttings from plants which had grown in the greenhouse for a number of years. *Helianthus annuus* and *Phascolus vulgaris* were grown from seeds.

(2) WATER CONTENT METHODS

In determining the wilting coefficient of *Equisetum fluviatile*, and *Ranunculus sceleratus* essentially the same wax-seal method recommended by Briggs and Shantz (1912: 10) for the direct determination of the wilting point was used. The plants, however, were grown approximately six weeks in soil sifted through a two millimeter screen before being sealed for wilting. The exact time elapsing before the seal was applied differed with the season because the plants started in spring grew much more rapidly than those started in fall. Through an inadvertence *Equisetum hyemale* growing in sandy loam was used for the wilting coefficient and consequently a direct comparison with the others cannot be made.

In most cases *Equisetum* wilts very suddenly, the collapse of the upper part of the plant indicating that the critical point in the absorption of water has been reached. Very similar wilting effects result from other causes. If the wax is too warmwhen put around the stem the latter is injured and the whole plant collapses. This can be distinguished from true wilting by the

Fig. 1. A *Phaseolus vulgaris* in the same pots with *Equisetum hyemale*, *E. arvense*, and *E. fluviatile*, to determine the time of wilting. B *Helianthus annuus* in the same pots with *Equisetum hyemale*, *E. arvense*, and *E. fluviatile*, to determine the time of wilting.

collapse of the tissue at the point of sealing. A damping-off fungus also produces a sudden wilting, but in this case the stem always shows decay at the surface of the soil. In wilting due to lack of water in the soil, the top of the plant collapses first and the stem is not injured at the surface of the soil or at the point of sealing.

Ranunculus sceleratus on the other hand has no definite wilting point. The time of the yellowing of the first leaves of the rosette varies from four to eight days. By the time the younger parts wilt the older parts are completely dead. As these parts continue to draw water from the soil and evaporate it from their leaves (Briggs and Shantz 1912: 47), the coefficients are too low.

The relative time of wilting was compared with that of mesophytes such as *Helianthus annuus* and *Phaseolus vulgaris* by growing them in the same pots (fig. 1) and allowing them to wilt. In some cases the *Equisetum* and the beans and sunflowers were started in the same pots, in others, plants from ten to twelve days old were transplanted into the same pots, care being taken to injure the roots as little as possible. Two weeks were allowed for the plants to establish themselves and develop good root systems before sealing.

(3) TRANSPIRATION METHODS

Water loss by the plant was determined by weighing potted plants as this is the most convenient and reliable of the several methods for measuring transpiration. The plants were either sealed in glazed pots or in Ganong aluminum shells. The wax used as a seal was made of twenty parts of vaseline to eight parts of paraffin, the formula recommended by Briggs and Shantz (1912: 13). In cases where the wax was to be put directly on the soil, a piece of paper was cut to fit neatly over the top of the pot, dipped into the melted wax, and fitted in place. The edges were sealed by pouring more wax over the surface and slightly tipping the pot so that it would run up the sides. The object of the paper was to prevent the wax from creeping into

the soil when heated by the sun's rays. The plants themselves are very sensitive to heat so that the wax cannot be applied near the stems until it has cooled sufficiently to form a scum over the surface. The waxed paper also proved a satisfactory substitute for rubber on the Ganong shells.

The plants were grown in loam which had been sifted through a two-millimeter screen in order that absorption by the roots would be as nearly uniform as possible. Records of humidity and temperature during each experiment were made by a Draper self-recording hygrometer and thermometer.

The transpiration of two or more plants was compared on the basis of the number of grams of water lost per unit area. The stem and branches of *Equisetum* are almost cylindrical so that the determination of the area of the surface was comparatively simple. The diameter of a stem was measured with a vernier micrometer at the middle of the lowest and topmost internodes. These represented the extremes in size, and from the average, the average circumference of the stem was calculated. This multiplied by the length of the stem gave the area of the surface.

Leaf areas were found in two ways, by the planimeter and by weighing paper prints. Leaves with comparatively simple outlines were traced on paper and these retraced with the planimeter. After practice this could be done readily and the average reading of three tracings was recorded. This method has the advantage of giving the area directly but also has disadvantages in that the square inches must be converted into square decimeters, and that it is difficult to trace leaves with very toothed margins. In the paper weighing method either tracings or blue prints of the leaves were made and cut out with a scissors. The weight of these prints divided by the weight of one square decimeter of the same paper, multiplied by two gave the transpiring areas of the leaves. Table 1 shows how the two methods check with one another.

This comparison of the two methods shows an average difference of only three hundredths of a square decimeter. This was

TABLE 1

Comparison of planimeter and weighing methods of determining leaf areas

PAPER WEIGHT METHOD		PLANIMETER METHOD			DIFFERENCE
Wt. of leaf prints (grams)	Wt. of leaf prints (grams)	Area sq. d. m.	Area sq. in.	Area sq. d. m.	Sq. d. m.
0.500	0.18	0.72	10.72	0.69	0.03
0.533	0.26	1.04	16.60	1.07	0.03
0.538	0.44	1.65	26.04	1.65	0.03
Average area					1.14 sq.d.m.
Average difference					0.03 sq.d.m.
Error					3%

considered so small that the two methods might be used interchangeably. Whichever method was the more convenient under the circumstances was used to determine the areas.

(4) PHOTOSYNTHESIS METHODS

To determine the efficiency of *Equisetum* as compared with that of other plants with respect to the activity of the chlorenchyma in the manufacture of carbohydrates, determinations of the amounts of glucose present in the stem in the morning and evening were made. During the same period a record was kept of the transpiration and the results correlated. The chemical analyses were made by Miss Long according to a modification of the Munson-Walker method of testing for glucose.

(5) ADJUSTMENTS AND ADAPTATIONS

The adjustments of a plant to the physical factors of its habitat are most strikingly shown in the physiological responses of growth and transpiration to light and to the water content of the soil. To determine the effect of soil-water content upon growth, *Equisetum flaviatile* was grown with roots submerged in water, in mud, and in a soil-water content of 35%. All other factors were kept uniform by using the same volume of the same type of soil sifted through a 2 mm. screen. The plants

stood beside each other in the greenhouse bench so that they were subjected to the same conditions of temperature, humidity and light. The intensity of light in another group of plants was varied by placing plants in a muslin shade tent which cut down the light to 0.3% as measured by a photometer. Plants in the bench receiving normal sunlight in the greenhouse, or 50% full sunlight, served as checks.

A study of the position of the stomata was made according to the method worked out by Lloyd (1908:22). Thin slices of epidermis were cut out from the surface and plunged into absolute alcohol. Before using, the sections were transferred to a saturated solution of Congo red in absolute alcohol. After several days they were examined under the microscope. The stain deeply colored the cell walls so that the opening between the guard cells is easily observed.

Cross sections of the stems which had grown under varying soil-water contents for four months were made with the freezing machine and examined for structural modifications. Strips of epidermis were also studied for the number of stomata.

(*To be continued*)

VOLNEY MORGAN SPALDING

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One of the builders of American botany passed from this life on November 12, 1918. Professor Spalding was a member of the botanical staff of the University of Michigan for twenty-eight years, and for most of this period was head of the department. His was a life characterized by usefulness in science and by inspiration to his followers. As a pioneer teacher and investigator in science he shared the onerous labors of a few comrades as his name is now honored by many.

Possessing a charming personality and an unquenchable spirit of optimism, he promoted industry and harmony among his students upon whom he impressed his own remarkable zeal for the truth.

In his boyhood his parents moved from western New York to a farm near Ann Arbor where he grew to manhood. The sound of the college bells called him from the farm to the class rooms in which he spent most of his subsequent life. He graduated from the University in 1873 and taught for a few years in the High School of Battle Creek, Michigan. In 1876 he took up the work in botany in the University of Michigan which he followed until 1904. Twice during this time he visited European universities for advanced study and in 1894 received the degree of Ph.D. from Leipzig.

During much of the time of his professorship, the University of Michigan was developing what was then a new idea, viz: a coördinated system of public education beginning with the primer and ending with the collegiate degree. The university had to meet the responsibility of training teachers for the secondary schools if the system was to be a success, since it could not accept

the poor standards formerly prevailing. Botany, most of all subjects in the high school curriculum, needed to be rescued from its friends by whom it was regarded as being "especially adapted for edifying the minds of young ladies" in seminaries, and was taught by instructors whose learning did not extend much further than *Claytonia virginica* and *Erythronium americanum*.

VOLNEY MORGAN SPALDING

One of Professor Spalding's great services lay in giving scientific training to those who would teach natural sciences in the secondary schools, and in insisting that botany is a science of such great usefulness that it should be taught by one who was really prepared to do so. To appreciate the difficulties of scien-

tists of two score years ago we must remember that the laboratories of today did not then exist, especially in the young inland universities. Even on the seacoast the "laboratories" were more likely to be small rooms adjoining the herbarium cases in which collections of dried plants were taken for study and classification. Furthermore, science was hardly recognized as worthy of a place in the curriculum, by either students or faculty. Professor Spalding was the leader of a small, but determined group of scientists which fought for years before they succeeded in having work in the natural sciences recognized as equal in educational value to classics and worthy of the same diploma.

A vivid picture of his early laboratory and its work has fortunately been given by Professor Spalding himself:

> Twenty-five years ago, in one of our northern universities, a young instructor with a single assistant was engaged in the rather comprehensive task of teaching botany and biology. The botany consisted in part in the analysis of flowering plants by means of Gray's "Manual," and in studying the minute anatomy of leaves, stems, and other parts of plants, which the literary students studied under the name of structural botany, while, with a strong flavor of crude drugs, it was administered to the pharmacy class engaged in the study of adulterants.
>
> As for the books used, the "Centralblatt" was not in existence, but this mattered little, for neither was the enormous literature it has since recorded. The "Botanische Zeitung" was regularly published, but the library committee had no use for it, and much the same was true of most of the periodicals that every working botanist now finds indispensable; but we had Sachs's "Text-book of Botany" and the big picture book of LeMaout and Decaisne, and on the shelves were Sullivants' "Icones Muscorum" and dear old Berkeley, and Cooke's "British Fungi," with all their impossibilities, and last but not least, the reports of the government microscopist, of which we cannot speak particularly.
>
> The rest of the outfit was in keeping. Microscopes, of a certain sort, there were, but no other apparatus. Razors were sharpened on a well-hacked strap, iodine and sulphuric acid constituted the reagents and the enthusiasm of fellow adventurers in an unknown country kept up the courage of young men and women who walked by faith and saw but little.

The herbarium alcoves were gradually enlarged. New ideas crept in and brought apparatus. No matter, however, whether equipment was scanty or ample, his students learned from their teacher the nobility of honest endeavor and caught, in some measure, his spirit of optimism.

Professor Spalding rendered another great service to the state by his work on the problems of forestry. He saw the lumberman remove great forests of pine leaving, too often, desolation in its place. How to use the great natural resources of the forests without destroying them was the problem which he met, and to which he devoted years of hard work. He spent his vacations in the woods, travelled about the state at his own expense, talked, wrote, agitated, and kept the issue before the people. Today, the campus on which he worked possesses a modern school of forestry as one of the fruits of his labors. Where there was formerly opposition on the part of the landowners and lumbermen there is now coöperation in scientific and economic investigation.

Failing health compelled Professor Spalding gradually to lighten the weight of his labors. The year 1898–1899 was spent in southern California in recuperation. Finally, in 1904 he was compelled to relinquish entirely his work in the department at Ann Arbor which he had spent over a quarter of a century in building. After another year spent in southern California, he joined the staff of resident investigators at the Desert Botanical Laboratory of the Carnegie Institution at Tucson, Arizona. His labors at this place are partially embodied in his monograph on the "Distribution and Movements of Desert Plants," a noteworthy study of the intricate problems of vegetation in a semi-arid region. Professor Spalding was so far incapacitated by rheumatism that in 1909 it was necessary for him and Mrs. Spalding to move to the sanitarium at Loma Linda, California, where they resided until his death. Though suffering from severe physical infirmities his mind retained its youthful vigor, while his spirit radiated hope and cheer among the members of the sanitarium for nearly nine years.

Professor Spalding was president of the Michigan Academy of Science in 1897–1898 and of the Society for Plant Morphology

and Physiology in 1902. He was for many years an associate editor of the "Botanical Gazette" and later of the "Plant World."

In 1909 a group of his former students was moved to prepare a memorial as a token of their lasting gratitude to their honored teacher. In addition to sending him a congratulatory message engraved on vellum at the time of his sixtieth birthday, a bronze tablet was struck. The inscription on the tablet reads:

VOLNEY MORGAN SPALDING

In commemoration of the twenty-eight years of faithful service as teacher of botany in this university (1876 to 1904) and as a token of love and gratitude this tablet is erected by 100 of his former students.

Per naturae opera mentem ad humanitatem fingebat atque virtutem.

Done in MCMIX.

The tablet was erected in a prominent place in the recently completed botanical laboratory at Ann Arbor. It was formally dedicated at public exercises at which the President of the University presided.

To those who knew him, however, he is best remembered, not by tablets nor by monographs; but by the patient, sacrificing toil with which he helped to build American botany and by the lasting impression made on the lives of his students. The ideals of his life are summed up in a few splendid words which came from his own pen:

Service, first wrung from the unwilling slave, then the free will offering of the citizen and patriot, is now the honorable goal of the worker in science and here is no higher end to be attained.

BOOKS AND CURRENT LITERATURE

Rainfall and Plant Distribution in Australia. It does not require long experience in the observation of plant life in Australia to realize that in certain features it is peculiar. Everywhere one is struck with its fair degree of monotony. A closer analysis shows that this is in part due to the fact that there is comparatively little diversity in the foliage. And, also, the common saying in Australia that the plants shed their bark and not their leaves, has at least a moiety of truth, inasmuch as the perennials are as a whole sclerophyllous. In addition to these features there is a monotony of color, the advent of spring, for example, save for the burst of bloom, making relatively little difference in this respect. Such features as these point to the probability that the environmental conditions that prevail today may have been in operation over a very long period of time. Hence a study of the environment under which the plants are growing at the present, and to which their ancestors were probably exposed in past ages, is of particular interest. Such a study, limited to rainfall, has lately been put out by Dr. Griffith Taylor, and merits early notice.[1]

As is well known, the island continent has as a whole a low rainfall. A vast area, for example, situated west of the center receives less than 10 inches of rain annually. But, in general, the rainfall increases in amount and in reliability as one recedes from the center, and the margins may be well watered. The rains are largely seasonal with more or less dry mid-seasons. These features are satisfactorily explained by the position of Australia on the globe, by its extent, and its topography. In the north the continent comes under tropical conditions, and in the south under those of the temperate zone. The seasonal shifting north-south of the climatic complex operates to bring rains in the north in summer and in the south in winter. Between the two is a great stretch of country that is subject to neither tropical nor temperate conditions, although it may be affected by both. This is the desert. These various climatic conditions and relations are well presented in the memoir. Mention need be made here only of a very ingenious

[1] Taylor, Griffith. The Australian environment, especially as controlled by rainfall. Advisory Council of Sci. and Ind., Memoir No. 1. Melbourne, 1918.

solar-control model by which the areas of probable rainfall or dryness for any month of the year can be quickly shown.

Although the memoir as a whole treats only of rainfall, two instructive chapters are devoted to the author's climograph and hythergraph and are of much interest. The former has to do with the wet-bulb thermometer and relative humidity readings. Climographs of representative Australian stations in comparison with those for Berlin and London are given. Hythergraphs are shown for certain tropical stations in Australia and a composite hythergraph is evolved which is used as a comparison in an interesting figure giving those for various Indian economic plants.

An instructive vegetation map, based on the one by Diels, shows the situation of the great groups and their relation to the 10-inch isohyet. This map, together with the author's tabulated characterization of the rainfall as regards the times of its probable occurrence, leads one to suggest that very possibly the xerophytic stamp which so strongly marks the Australian vegetation, may be due to the fact that it is periodically exposed to drought. However that may be, it is shown that the "mulga" (*Acacia* spp.) regions receive rains in summer mainly, while the "mallee" (*Eucalyptus* spp.) are exposed to winter rains. In the savannah and savannah woodlands, both of which extend broadly latitudinally as well as longitudinally, the season of rain depends on the situation, being mainly in summer or winter, as the case may be. It is in restricted rain forests only that the rainfall is fairly uniform throughout the year. So far as the actual amount of precipitation in these various regions is concerned, it can be summed up as follows: The rainfall of the mulga and desert regions is under 10 inches. That of the mallee is 10 to 20 inches as is also that of the savannah. In the savannah woodland regions, however, it ranges from 15 to 50 inches annually. And, finally, in the rain forests the precipitation amounts to over 30 inches a year.

Omitting further account of the discussions relating to the general climatic conditions, which are very interestingly treated, I will briefly review the discussion of the regional correlations and rain origins, to which the major portion of the memoir is devoted.

The continent is conveniently divided into 15 regions and to each region is given a separate chapter. Regional maps showing rainfall and contours accompany formal presentation of the subject matter. Storm charts and graphs are freely used. A striking feature is the occasional employment of block models to illustrate possible topo-

graphical changes. Owing to my better acquaintance with portions of South Australia I will confine what I have to say to that state, particularly to the northern portion.

South Australia is divided by the author into two regions by an east-west line which corresponds very well to the 10-inch isohyet. In the north, the "Eyre" region, the leading industry is pastoral, while in the south it is agricultural. There are three leading physiographic regions in the Eyre region which are the western plateau, the central-eastern basin, and the south-eastern Flinders ranges. The altitudinal range is approximately 4000 feet, reaching from −39 feet of Lake Eyre, the summits of the Flinders and the Musgraves, the latter of which may to be over 4000 feet. Lake Eyre constitutes the receiving basin of an area approximating 500,000 square miles in extent, only a small proportion of which is within the state. In earlier (Cretaceous) times the drainage of this vast region is supposed to have emptied into the Southern ocean through lakes Eyre, Fromme, and Torrens. By various depressions and elevations the central portion was cut off from the sea, and the ancient drainage system has lost its earlier character. The amount of water that flows along the former lanes is at present of little importance.

The vegetation of the region is treated in a half-dozen paragraphs. In the north-east quarter are the barest regions where long lines of sand or loam ridges run approximately north and south. Normally in such conditions mulga, *Acacia aneura*, grows sparingly on the ridges, salt bushes of whatever kind occur on saline flats, and species of *Eucalyptus* and *Acacia* are to be found in the drainage channels. In the west where there are sand ridges, the mulga ridges alternate with spinifex flats. Here are also desert gums, *Eucalyptus eudesmioides*, mallee and "oaks," *Casuarina* sp. In the mountains of the west there are *Santalum*, *Melaleuca*, *Callitris* (?), and others. The extreme south-west is different from the rest of the region owing to the porous nature of the limestone of which it is composed. This is the Nullarbor plain (where species of salt bush dominate although in the hollows *Santalum* and *Acacia* spp. occur). In the high lands of the west grasses are abundant where the places are favorable (and the same could be said of other similar regions, as, for example, about Copley).

The plants of the Eyre region are subject to the most arid condition to be found in Australia. The driest station, according to Taylor, is Kanowana, which is east of Lake Eyre. Here the average rainfall for twenty years is 4.24 inches. He finds that there is an arid "axis"

which extends north-west and south-east across the north-east portion of the region. Oodnadatta, with a rainfall of 4.68 inches is situated along this line. The area with less than 5 inches of rainfall is over 36,000 square miles. The rain in the extreme north of the Eyre region is due to northern, tropical, influences. Oodnadatta, however, which is somewhat south of the northern boundary of the state, receives rain in winter as well. But those of the south-west in particular are in winter only.

In presenting an account of the character of the rainfall, which is summarized in an instructive table, it is found that 64 per cent is of the trough type, 20 per cent antarctic, 10 per cent tropic, and 6 per cent non-isobaric. In other words, one-fifth of the rainfall is that of winter, one-tenth is that of summer, and far the most occurs from a union of lows originating in the south and north, and do not appear so strictly seasonal as the other two. The north-south swing of the climatic complex is 1200 miles, or more. Since the northernmost point attained by the center of highs coincides fairly well with the north boundary of the state, the southern extremity reached is far south of the Eyre region, or indeed of South Australia. The effect of this seasonal swing is graphically shown by the author for the whole of Australia, as mentioned above, in his solar-control model. The influence of the swing on the rainfall of the Eyre region can be easily and strikingly shown by inserting the outlines of the region on the model. The types of winter and summer storms are various, and need not be detailed here. They are illustrated by numerous charts and fully described

The general treatment of the rainfall as an environing factor of the plants has been from the standpoint of a meteorologist, one would judge from reading the work, rather than from that of a botanist, and possibly this would ensure its better handling! Certainly the work is well done. One cannot help questioning, however, the values of storms of the same amount, or, which is not the same thing, *rainfalls* equal in amount. It is clear that a 5-inch rainfall which is mostly in summer, for example, may be less effective than a rainfall similar in amount but occurring mainly in winter. This is largely owing to the unequal rates of evaporation in the two seasons, and its corresponding effect on plants. Then also, it seems possible that storms at any season which measure 0.15 inch or less, are of little use to plants, although a succession of them a few days apart would make a fair showing on the rainfall totals. That this may be of no little importance is suggested by the fact that at Oodnadatta in 1906, for example, 56 per cent of the

rainfall occurred in such small amounts. Whether a storm is sufficiently heavy to be of benefit to plants must depend on several features among which would be the season, the kind of soil, and the amount of moisture in it at the time of the storm. Measurements which the reviewer made of rain penetration at different stations in the Eyre region showed, as a matter of fact, that it required a surprisingly smart shower to effect any marked moisture penetration. It would be a very interesting and useful thing if the various meterological offices would make an investigation into what constitutes an effective fall of rain and put out the same together with rainfall totals.

Finally, it would have made the work of considerable more service, it seems clear, had there been added a good index. Reference books without indexes are badly handicapped.—W. A. Cannon.

The Conditions of Fruitfulness.—In their bulletin on Vegetation and Reproduction with special Reference to the Tomato, Kraus and Kraybill[1] have presented physiological and biochemical studies as important evidence in the elucidation of the problem concerned with the interrelations existing between fertilization, vegetative vigor and seed and fruit development. It has been shown that at least some of the instances of sterility considered to be the result of physiological incompatibility may be due to the state or condition of nutrition of the plant itself. Furthermore, both environmental and hereditary factors must be considered in any attempted explanation of the reproductive and vegetative behavior of plants. The results of the experiments tend to support the theory they present, namely that vegetative vigor and reproductive vigor are dependent upon a definite relationship between the carbohydrate and nitrogenous compounds in the plant. Some of the important conclusions follow:

Plants grown with an abundant supply of available nitrogen and the opportunity for carbohydrate synthesis are vigorously vegetative and unfruitful. Plants grown with an abundant supply of nitrogen and then transferred and grown with a moderate supply of available nitrogen are less vegetative but fruitful. Plants grown with an abundant supply of nitrogen and then grown with a low supply of nitrogen are very weakly vegetative and unfruitful. Fruitfulness is associated neither with highest nitrates nor highest carbohydrates, but with a condition of balance between them.

[1] Kraus, E. J. and H. R. Kraybill. Vegetation and reproduction with special reference to the tomato. Bul. 149, Oregon Agr. Col. Exp. Sta 1918.

The great variations in the amount of carbohydrates in plants grown under different nutrient conditions, and in different parts of the same plant, indicate that in studying problems concerned with plant metabolism it is necessary to know the specific environment of the plant as a whole, and of its several parts.

Lack of fruit development is not alone due to the lack of pollination or fertilization, nor are the greatest number of flowers produced by conditions favoring highest vegetation or markedly suppressed vegetation. Pruning, as it effects the balancing of the carbohydrate supply with the mositure and nitrogen supply will promote or retard fruitfulness.—R. P. HIBBARD.

HEIGHT GROWTH OF YOUNG CONIFERS.—It has been a matter of common observation with foresters that the height growth of young conifers is more closely dependent on environmental conditions than is the growth in diameter. Two papers have recently appeared describing efforts to determine which of the environmental conditions, or what combination of them, is most important to vigorous height growth.

Brewster,[1] working at Priest River, Idaho, has compared the growth of western larch (*Larix occidentalis*) for the years 1912–16, finding the greatest growth in 1914, correlated with relatively high temperatures, a maximum of sunny days and a generous, well distributed rainfall. He attributes the best growth to the combined effect of these climatic conditions.

Pearson[2] has investigated the growth of western yellow pine (*Pinus ponderosa*) in the very dissimilar climate near Flagstaff, Arizona. This tree makes its greatest height growth during the months of lowest precipitation: April, May and June. When the growth depends solely on the precipitation of earlier months it is very small: when rains occur in April and May they result in a marked increase of height growth. The curves of relative humidity and number of cloudy days for the years 1909–17 show a correlation with the curve of height growth which is almost as close as that of the precipitation of April, May and June. Temperature is regarded by the author as being most important in its

[1] Brewster, D. R. Relation between height growth of larch seedlings and weather conditions. Jour. Forestry, 16: 861–870. Dec. 1918.

[2] Pearson, G. A. The relation between spring precipitation and height growth of western yellow pine saplings in Arizona. Jour. Forestry, 16: 677–689. Oct. 1918.

relation to the general moisture conditions. Higher temperatures are usually coexistent with adverse moisture conditions and therefore fail to produce the acceleration of growth that might be possible with a more abundant soil moisture supply. Evaporation bears an inverse relation to growth throughout most of the eight year period, indicating that the high transpiration which it causes in this semi-arid region is deterrent to growth.—Forrest Shreve.

NOTES AND COMMENT

Prof. W. F. Gericke, of the University of California—at present working at the Laboratory of Plant Physiology of the Johns Hopkins University on the salt nutrition project of the Division of Biology of the National Research Council—presented what may be some rather startling results at the Baltimore meeting of the Physiological Section of the Botanical Society of America, under the title, A preliminary test of the influence of temperature upon the effect of the physiological balance of the nutrient solution as related to germination in wheat. In experimentation on the relation of germination in wheat to salts, salt proportions and temperature, following out a rather elaborate scheme, it appears that the salts and salt proportions of the medium that are best for germination with one maintained temperature are not at all the same as those that are best with another maintained temperature. In other words, the optimum nutrient solution for wheat germination is different for different temperatures, and a statement of the temperature employed must always accompany any statement about physiological balance in the nutrient medium. Conversely, the optimum temperature for wheat germination cannot be stated without an accompanying statement regarding the concentration, salts and salt proportions of the nutrient solution referred to. So far as this work has gone, it appears that the percentage of germination and the rapidity of the early development of the wheat seedling depend upon the following five conditions, at least: (1) the seed used (internal conditions), (2) the salts used in the medium, (3) the salt proportions in the medium, (4) the total concentration (osmotic value) of the medium, and (5) the temperature. Of course it is to be expected that varying temperatures may exert very different influences from those exerted by any maintained temperatures (only maintained temperatures have been studied), and also that the oxygen and carbon-dioxide relations will not be without influence on germination (these have not been quantitatively studied).

These results emphasize once more how futile physiological experimentation is unless it is carried out with all the influential conditions either controlled or quantitatively defined. It is the business of plant

physiology to establish some principles regarding the conditional control of plant processes, and the sooner we appreciate the need of quantitative definition of all effective conditions in every piece of experimental work, the more rapid may be our progress toward such principles. Since radiation (light) is a continually and irregularly varying condition in nature, since it is essential to the later growth of green plants but not for seed germination, and since it cannot readily be either measured or controlled (excepting by its practical elimination), the germination phase of plant growth offers the most promising field for true experimental studies. This phase may be studied without any light reaching the cultures; in other words, the radiation condition may be maintained at *zero* intensity for practically all effective qualities.

It is the purpose of this note to emphasize the importance of the general principle brought out by Gericke, and also to emphasize the possibility of really good experimentation if cultures can be kept in darkness, as in the case of germinating seeds. Methods are already available for the control of maintained temperatures, and probably for that of the oxygen and carbon-dioxide relations. Since neither light nor the evaporating power of the air are generally important influential conditions in seed germination, these two environmental features may be practically eliminated from the discussion, by maintaining them nearly at *zero* intensity, when seed germination is the process to be studied.—B. E. Livingston.

Dr. W. Howard Rankin has recently published, in the MacMillan Company's series of Rural Manuals, a treatise on the diseases of trees. The general diseases affecting all trees are treated collectively, followed by chapters on the specific diseases of all the hardwoods and conifers of economic or ornamental importance in the United States. Symptoms and causes are fully described and remedial measures are given so far as known. There are brief chapters on tree surgery and methods of spraying. References to original papers are given under each disease.

WATER REQUIREMENT AND ADAPTATION IN EQUISETUM

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(*Continued*)

III. EXPERIMENTAL RESULTS

General Outline of Experiments.

(1) Water content of the soil.
- (a) Maximum and Minimum.
- (b) Wilting coefficient of
  - *Equisetum fluviatile*
  - *Equisetum hyemale*
  - *Ranunculus sceleratus*
- (c) Time of wilting
  - (1) *Equisetum fluviatile* and *Helianthus annuus*
    Equisetum fluviatile and *Phaseolus vulgaris*
  - (2) *Equisetum hyemale* and *Helianthus annuus*
    Equisetum hyemale and *Phaseolus vulgaris*
  - (3) *Equisetum arvense* and *Helianthus annuus*
    Equisetum arvense and *Phaseolus vulgaris*

(2) Water loss by the plant
- (a) Relation of transpiration to plant functions
- (b) Comparative transpiration
  - *Equisetum fluviatile*
  - *Equisetum hyemale*
  - Xerophyte: *Bryophyllum calycinum*
  - Mesophyte: *Helianthus, Phaseolus vulgaris*
  - Hydrophyte: *Ranunculus sceleratus*
- (c) Guttation.

(3) Transpiration and photosynthesis

(4) Physiological responses
- (a) Growth and soil-water content
- (b) Growth and light intensity
- (c) Transpiration of soil-water content
- (d) Stomatal behavior

(5) Adaptations.

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1. WATER CONTENT OF SOIL

(1) *Determination of maximum and minimum soil water content*

Two series of *Equisetum fluviatile* were run from November 4, 1916 to December 21, 1916 in soil-water contents varying from roots submerged in water to a holard of 9%, based upon the dry weight of the soil (see table 2). In series A the soil was sifted through a 5 mm. screen to give uniformity while in series B the soil was not sifted. In all other respects the series were duplicates. Plants numbered *1* grew in an inch layer of soil covered with three inches of water. Plants numbered *2* grew in porous pots standing in water. The others grew in a four inch layer

TABLE 2

Average soil-water content in two series of Equisetum fluviatile

SERIES A SOIL SIFTED		SERIES B NOT SIFTED	
	per cent		*per cent*
No. 1 Submerged		No. 1 Submerged	
No. 2	60	No. 2	58
No. 3	33	No. 3	37
No. 4	23	No. 4	30
No. 5	17	No. 5	18
No. 6	12	No. 6	9

of soil (2500 cc.) in eight inch glazed jars. Buds of approximately the same size and with the same amount of rootstock were used to plant in each pot so that none would have the advantage of a larger stored food supply. The amount of water added weekly was measured and recorded. A set of soil samples was taken every two weeks.

The plants in No. 5 and No. 6 withered when about 2 inches above the ground while those in No. 4 grew to be 8 inches high. Very few branches were developed and these dried at the tips. The best plants were obtained in No. 1 and No. 2, those growing in mud having slightly more branches than those with the roots submerged. Thus, *Equisetum fluviatile* demands a high amount of moisture in the soil, the range being from 23% to saturation with the optimum at the highest concentrations.

(2) *Wilting coefficient*

a) *Separate cultures.* *Equisetum fluviatile* and *Ranunculus sceleratus* were grown in loam with a water content from 35–45% maintained by keeping the pots in deep saucers filled with water. The wilting point was determined by the wax seal method. At the time of sealing, the *Equisetum* had grown six weeks and the *Ranunculus* two months under the conditions

TABLE 3

Soil-water content at time of wilting, in Equisetum, Ranunculus and Helianthus

Equisetum fluviatile		
Plant (1)	23.1	Loam
Plant (2)	24.4	
Plant (3)	23.0	
Plant (4)	30.0	
Average	25.1	
Ranunculus sceleratus		
Plant (1)	13.5	Loam
Plant (2)	11.0	
Plant (3)	14.1	
Plant (4)	14.7	
Average	13.3	
Equisetum hyemale		
Plant (1)	5.3	Sandy loam
Plant (2)	5.3	
Plant (3)	4.2	
Plant (4)	4.7	
Average	4.9	
Helianthus annuus		
Plant (1)	5.8	Sandy loam
Plant (2)	5.4	
Average	5.6	

mentioned. A series of *Equisetum hyemale* growing in sandy loam was also sealed for wilting. Because of the differences in the soil the latter were checked against the wilting of two sunflowers also growing in sandy loam. The results are shown in table 3.

In order to check the soil water requirements of *Equisetum* against those of typical mesophytes the following series of experiments were undertaken.

(b) *Cultures with mesophytes.* The method of growing the plants in the same pots is shown in figure 1, and the results are given in table 4.

The table shows (except in the case of *Equisetum hyemale*) that *Equisetum* wilted before the mesophytes when the root

TABLE 4

Relative time of wilting of Equisetum and mesophytes grown simultaneously in the same pots

PLANTS	WILTING OF EQUISETUM	WILTING OF MESOPHYTE	REMARKS ON ROOT SYSTEM
	days	*days*	
Equisetum fluviatile			
Helianthus annuus.	2	10	Both plants had good root systems well distributed in pot
Helianthus annuus.	7	12	Both plants had good root systems well distributed in pot
Phaseolus vulgaris	2	17	Good root systems
Phaseolus vulgaris	12	19	
Equisetum hyemale			
Helianthus annuus	15	15	Good root system
Helianthus annuus	13	17	Fair root systems
Phaseolus vulgaris	13	later	Good root systems but not very well distributed
Phaseolus vulgaris	10	bean injured	Root system of bean very poor. Equisetum showed signs of wilting first
Equisetum arvense			
Helianthus annuus.	5	12	Good roots
Phaseolus vulgaris.	7	yellowing on 7th day	Root system of bean poorly developed Equisetum roots good

systems of both were in good condition and well distributed in the pots. In some cases the exact number of days for the wilting of the mesophytes was not obtained, but the fact that the *Equisetum* wilted first is indicated. The discrepancies in the cases of *Phaseolus* are attributed to the poorly developed root

systems, but the results with *Helianthus* show beyond a doubt that it is able to draw water from the soil after *Equisetum fluviatile* and *Equisetum arvense* are dead. Figure 2 shows *Equisetum fluviatile* wilting while both *Helianthus* and *Phaseolus* are in good condition. The conclusion to be drawn from this evidence is that the latter are less hydrophytic than either *Equisetum*

Fig. 2. *Equisetum fluviatile* wilting. *Phaseolus vulgaris* and *Helianthus annuus* still turgid.

arvense or *Equisetum fluviatile*. *Equisetum hyemale* differs from the other two in that it seems to be mesophytic in its relations.

These results on the wilting of *Equisetum*, *Helianthus*, and *Phaseolus* agree with the work of Hedgecock (1902:65) who states, in his conclusion that "the ability of plants to take water from the soil varies in an ascending scale from hydrophytes,

through mesophytes, to xerophytes" and the view of Clements (1905: 31) that "a plant of xerophytic tendency is naturally able to remove more water from the same soil than one of mesophytic or hydrophytic character." Briggs and Shantz (1912: 75) found the wilting coefficient of a great number of plants with which they worked to vary but little, or from 92 for Japan rice to 106 for a variety of corn, with 100 as the standard. From their results of simultaneous wilting of plants grown together in the same pots, the writers conclude that one plant is not able to draw more moisture from the soil than another. The results of the present investigation indicate that certain mesophytes are able to take more moisture from the soil than the hydrophytic species of *Equisetum* can.

2. WATER LOSS BY THE PLANT

(*1*) *Comparative transpiration*

A comparison of the series in Table 5 shows that in the amount of water lost by transpiration *Equisetum fluviatile* exceeds both the mesophytes and the xerophytes. *Ranunculus sceleratus*, which is a typical hydrophyte, loses only eight to nine tenths the amount of water that *Equisetum fluviatile* does. The mesophytes *Helianthus annuus* and *Phaseolus vulgaris* lose from two to six-tenths as much, while the xerophyte, *Bryophillum calycinum*, loses only one tenth as much. In other words *Equisetum fluviatile* transpires from two to five times as much water from its surface as do two typical mesophytes, and ten times as much as a typical land xerophyte. *Ranunculus* is an exceedingly plastic species which accounts for its ranking below *Equisetum*, for during the experiment the roots of the former were not in water. *Helianthus* is an exceedingly wasteful plant as far as water loss is concerned which explains the transpiration being higher than in the case of *Phaseolus*. The conclusion to be drawn from this evidence is that *Equisetum fluviatile* is unquestionably a hydrophyte.

These results agree very closely with those of Sampson and Allen (1909: 55) who found that *Scirpus lacustris* also a "bog xerophyte" loses twice as much water as *Helianthus annuus*.

TABLE 5

Comparative transpiration of Equisetum and other plants

SERIES	AVERAGE TEMPERATURE	AVERAGE HUMIDITY	PLANTS	TOTAL LOSS	AREA SQ. DM.	LOSS PER SQ. DM.	AVERAGE LOSS	RATIO
	°F	per cent		grams		grams		
1	80	57	*Equisetum fluviatile*	7.3	0.38	19.2		
			Equisetum fluviatile	7.4	0.43	17.2	18.8	1.0
			Equisetum fluviatile	6.0	0.30	20.0		
			Bryophyllum calycinum	5.5	2.18	2.5	1.9	0.1
			Bryophyllum calycinum	5.8	4.54	1.3		
			Ranunculus sceleratus	27.4	20.8	13.2		
			Ranunculus sceleratus	27.0	2.50	10.4	14.5	0.8
			Ranunculus sceleratus	50.0	3.02	19.8		
2	67	60	*Equisetum fluviatile*	10.9	0.37	29.5		1.0
			Ranunculus sceleratus	77.4	3.02	25.6		0.9
			Equisetum hyemale	68.5	3.83	17.9		0.6
			Helianthus annuus	62.5	4.24	14.7		0.5
			Phaseolus vulgaris	28.4	5.42	5.2		0.2
			Bryophyllum calycinum	9.9	4.54	2.2		0.1
3	65	60	*Equisetum fluviatile*	9.9	0.84	11.8		1.0
			Equisetum fluviatile	7.8	0.75	10.4		
			Equisetum arvense	4.0	0.84	4.8		0.4
			Equisetum arvense	4.2	0.89	4.7		
4	44	39	*Equisetum fluviatile*					
			Plant 1	5.3	0.38	13.9		
			2	10.0	0.68	14.7	152.2	1.0
			3	5.1	0.30	17.0		
			Helianthus annuus					
			Plant 7	21.3	2.20	9.7		
			8	29.0	3.15	9.2	9.8	0.6
			9	40.8	3.91	10.4		
			Phaseolus vulgaris					
			Plant 4	48.7	6.51	7.5		
			5	53.5	8.82	6.1	6.5	0.4
			6	20.0	3.47	5.8		

Comparing the transpiration of the different species of *Equisetum*, it is found that *Equisetum hyemale* loses but six-tenths as much water as does *Equisetum fluviatile* and that *Equisetum arvense* but four tenths as much, showing that these two are more mesophytic species.

(2) *Guttation*

Leaves of many species of plants, among which the best known are aroids, fuchsia, cabbage, and nasturtium, exude drops of water from their surface when transpiration is checked by

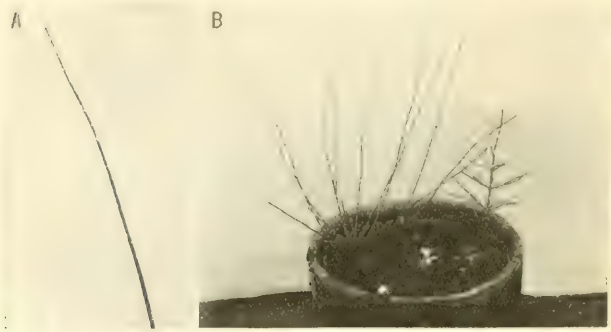

Fig. 3. A. Stem of *Equisetum hyemale* showing drops of water exuded by guttation. B. *Equisetum arvense* showing drops of water exuded by guttation.

external factors. (Sachs 1887: 278). Usually the water is forced out of permanently open stomata or water pores at the end of the veins. Although a common phenomenon, it is scarcely to be expected in a xerophyte. During the week of May 18–23 on four successive cloudy mornings, all three species of *Equisetum* were found to be guttating vigorously. In some cases the drops of water were 4 mm. in diameter, and 25 to 50 occurred on single stems. Old stems as well as young were exuding water (fig. 3). On these mornings the relative humidity in the greenhouse was 72%. The plants were then placed under bell

jars and the following morning large drops of water were found at the nodes between the points of the leaf scales and much smaller ones in the grooves of the internodes at positions corresponding to those of the stomata.

This furnishes additional evidence that *Equisetum* is not a xerophyte and particularly a "bog xerophyte" whose roots are supposed to have low absorption powers.

(3) TRANSPIRATION AND PHOTOSYNTHESIS

Relative transpiration and photosynthetic efficiency of *Equisetum fluviatile*, *Helianthus annuus* and *Phaseolus vulgaris*.

This experiment was done in cooperation with Miss Frances Long who determined the photosynthate.

The plants for this experiment were grown in soil kept saturated with water. The morning of the experiment the pots were placed in Ganong aluminum shells filled with water. Evaporation from the soil was avoided by covering it with a layer of waxed paper held in place by the aluminum ring. The space between the plant and paper was sealed with the Shantz mixture of paraffin and vaseline.

For the photosynthate readings similar plants were used for the morning and noon readings, since those used for transpiration could not be destroyed until evening.

Leaf prints were made of the leaves as soon as cut and the areas found by a planimeter. The leaves were killed in chloroform and dried in a steam oven at 90°. The glucose determination was made by the modified Munson Walker method used in Miss Long's photosynthate experiments.

The experiment was carried on May 4, 1917. The temperature and humidity conditions were as shown in table 6.

A glance at table 6 shows that *Equisetum* transpires 1.5 as much as *Helianthus* and 2.3 times as rapidly as *Phaseolus*. *Helianthus* loses 1.5 times the amount of water lost by *Phaseolus*. *Helianthus* is regarded as a very wasteful plant so far as water efficiency is concerned.

Helianthus shows 1.8 the ability to make carbohydrates shown by *Equisetum*, while *Phaseolus* is three times as efficient as

TABLE 6

Comparative transpiration of Equisetum and other plants, 7.30 a.m. to 5.30 p.m., May 4, 1917

The humidity and temperature were respectively as follows: 7.30 a.m., 70%, 70°; 12 noon, 28%, 78°; 5.30 p.m., 20%; 85°

PLANT	LOSS GRAMS H_2O	AREA SQ. D.M.	GRAMS H_2O LOST PER SQ D.M.	AVERAGE LOSS PER SQ D.M.
Equisetum fluviatile				
Plant 1	5.3	0.38	13.9	
2	10.0	0.68	14.7	15.2
3	5.1	0.30	17.0	
Helianthus annuus				
Plant 7	21.3	2.20	9.7	
8	29.0	3.15	9.2	9.8
9	40.8	3.91	10.4	
Phaseolus vulgaris				
Plant 4	48.7	6.51	7.5	
5	53.5	8.82	6.1	6.5
6	20.0	3.47	5.8	

TABLE 7

Comparative photosynthate of Equisetum and other plants. Readings under same conditions as in table 6

PLANT	GMS. DRIED LEAF USED	AREA SQ. D.M.	GLUCOSE TOTAL MGS.	GLUCOSE MGS. PER SQ. D.M.	MGS. GLUCOSE PER SQ. D.M. DURING DAY
Equisetum fluviatile					
7.30 a.m.	0.2100	0.6	17.4	29.0	
5.30 p.m.	0.2884	0.68	30.9	44.0	15.0
Helianthus annuus					
7.30 a.m.	1.0446	3.785	2.0	0.52	
12 noon	0.9354	2.907	33.0	11.35	10.83
5.30 p.m.	0.6674	2.68	76.5	28.54	28.02
Phaseolus vulgaris					
7.30 a.m.	1.509	7.54	126.7	16.81	
12 noon	1.015	5.17935	272.4	52.59	35.78
5.30 p.m.	2.4540	7.67	762.4	61.72	44.91

Equisetum (table 7). *Phaseolus* makes 1.6 times as much photosynthate as *Helianthus*. The low efficiency of *Equisetum* may be accounted for by the fact that the stem is the photosynthetic organ rather than the leaves. The position of the stem prevents the rays of the sun from falling directly on the surface so that a given amount of light is spread over a greater area. These slanting rays which reach it are of much less intensity than the direct rays and thus the source of energy for the photosynthetic work is much reduced.

Helianthus has an epidermis covered with hairs which serve as a light screen and cut out 70% of the light which strikes the epidermis. *Phaseolus* epidermis screens out 45% of the light incident upon it. The choloroplasts are then functioning not in bright light, even though the leaves are in full sunlight, but in 30% and 55% relative light intensity.

It is interesting to note that the photosynthetic efficiency in these three species is in inverse proportion to the amount of transpiration.

(4) PHYSIOLOGICAL RESPONSES

(1) Growth and water content

A series of *Equisetum fluviatile* was grown with roots submerged, roots in mud, and roots in a water content of 35% from April 2, to May 18. The effect of the varying water contents on the size of the plants is shown in plate 5. The following is the height of each:

Submerged. . .80.1 cm. Mud. . . .80.5 cm. 35%. . . .68.2 cm.

As shown on the plate almost no branches developed on the plant in 35% water content. With all the plants used in the greenhouse growth was best in mud, although in many cases the difference between the plants growing in mud and those with submerged roots was very slight.

(2) Growth and light intensity

Plants of *Equisetum fluviatile* were grown in a muslin shade tent which cut down the light to 3% and in the normal light of

the greenhouse, or 50% full sunlight. The effect is shown in figure 4, B. At the end of six weeks the plant from the shade tent was 7.4 cm. high and the other 80.0 cm. high. These plants grew in mud.

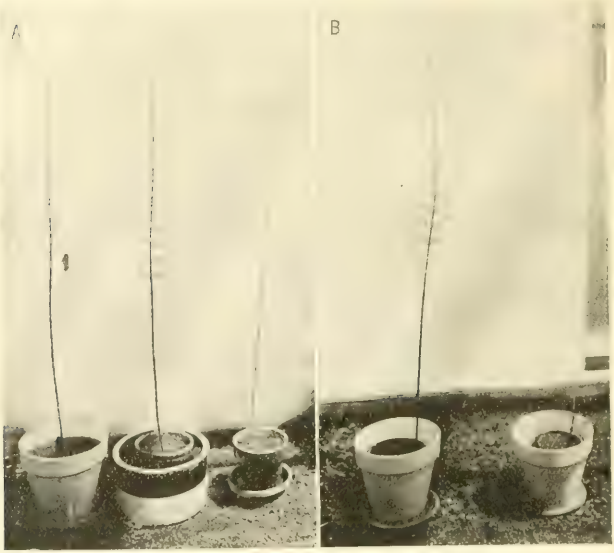

Fig. 4. A. *Equisetum fluviatile* showing effect of varying soil-water contents on growth. Left, submerged; centre, mud; right, 35%. B. *Equisetum fluviatile* showing effect of varying light intensities on growth. Left, 50%; right, 3%.

The results show that both water content and light intensity have a marked effect on growth in *Equisetum fluviatile*.

(3) *Transpiration and water content*

The effect of the three water contents on the amount of transpiration was determined for *Equisetum fluviatile*. To check the

results obtained the experiment was repeated three times with twenty plants. The difference in the amounts of water lost are shown in the graph in figure 5.

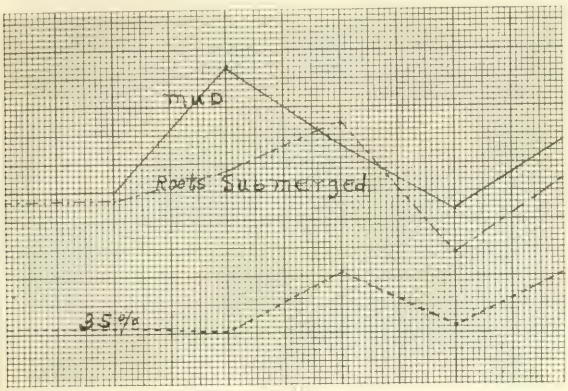

Fig. 5. Graph showing the effect of soil water content on transpiration.

The plants growing in mud lost the most water while those in soil of 35% water content lost the least.

(4) *Stomatal behavior*

Equisetum hyemale has 36 stomata per square millimeter of surface while *Equisetum fluviatile* has 118. In both cases the stomata are sunk in grooves resembling the modifications of a xerophyte. A set of readings on the position of the guard cells in the epidermis of *Equisetum hyemale* at 8 a.m., 12 noon, and 4 p.m. and an hourly series from 10 p.m. to 3 a.m. showed no difference in the size of the opening between the cells. During the night epidermis from both old and young stems were taken. This fixed position of the stomata explains why *Equisetum* can lose so much water per unit area by transpiration and guttation.

(5) ADAPTATIONS

That *Equisetum fluviatile* is a very stable form is proved by the fact that no structural differences could be discovered in cross sections of the stems growing in the different water contents. The epidermis was also studied for differences in the number of stomata but the average number per square millimeter did not vary.

The results of adaptation experiments were entirely negative. No structural differences could be discovered in the epidermis chlorenchyma, vascular tissue, or air space from the cross section of *Equisetum fluviatile* which had grown in the varying water contents, from November, 1916, to April, 1917, in the greenhouse. Sections of epidermis were also studied for the number of stomata but the average per square millimeter did not vary. These results correspond with those of E. S. Clements (1905: 87) who found no variation in certain xerophytic forms grown under varying conditions of water content.

IV. SUMMARY AND CONCLUSIONS

1. The results of the present investigation of the water requirements of *Equisetum fluviatile* show that this species requires a higher concentration of water in the soil in order to maintain its normal functions. The amount of water remaining in the soil at the death of the plant is greater than the amount at the death of *Ranunculus sceleratus*. When growing in the same soil mass with *Helianthus annuus* and *Phaseolus vulgaris*, *Equisetum* wilts first. A comparison of the transpiration shows that the water loss is much greater than from the mesophytes and the xerophytes with which it was compared. *Equisetum fluviatile* is therefore to be considered a true hydrophyte.

2. The high transpiration is correlated with low photosynthetic efficiency as compared with *Helianthus annuus* and *Phaseolus vulgaris*.

3. The difference in the time of wilting between *Equisetum* and the mesophytes with which it was compared shows that the

range in the amount of water that plants can take from the soil is greater than indicated by the work of Briggs and Shantz.

4. The fact that *Equisetum* can adjust itself to physical changes in the habitat by marked physiological responses but gives negative results as to adaptation indicates that the xeromorphic features are extremely stable structures and that adaptation to hydrophytic conditions has come about through the development of air-spaces, diaphragms, and permanently open stomata.

5. The great amount of water lost through transpiration and guttation indicates that this species does not grow in the xerophytic regions of bogs because of its low absorptive powers, as Dachnowski maintains, and that it cannot be considered an actual xerophyte at all. Its xerophily is only superficial and is probably due to the persistence of ancestral structures, now compensated by adjustment and by adaptation in the aerenchym.

6. Since the structure and habitat of the Paleozoic *Calamites* and Mesozoic *Equisetum* were essentially the same as those of the present day form, the apparent xerophily cannot be considered as an indication of a dry climate, of a physiologically arid habitat, because the water lost by the plants is great and means of checking it are absent. It is probable that the superficial xeromorphy of *Equisetum* was acquired in a cold arid period, such as the Permian.

7. The hydrophytic nature of *Equisetum fluviatile* places it in the hydrarch succession. It usually plays only a secondary part in the various kinds of swamps where it probably holds its place as a relic of former coseres. Successionally it is a member of the reed-swamp or sedge-swamp associes, usually forming a socies.

8. *Equisetum hyemale* and *Equisetum arvense* are found in much dryer areas than *Equisetum fluviatile*. A comparison of their transpiration per unit area shows that the former are more mesophytic in their tendencies. This accounts for the fact that these two species are capable of invading grass land.

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THE RELATION OF IRRIGATION TO HUMIDITY IN A RECENTLY RECLAIMED DESERT

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The Imperial Valley of California, which is the subject of this paper, offers many very interesting studies. It comprises the major portion of the Salton Basin, an area which is below sea level, and at the lowest portion of which lies the Salton Sea. The water of this sea is strongly alkaline through the age-long concentration by the excessive evaporation of the periodic inundations occasioned by the overflowing of the Colorado River.

The Imperial Valley is geographically a part of the great Colorado Desert. As recently as 1900 it was a desolate uninhabited waste of typical southwestern desert which supported only creosote bush, mesquite, salt bush, arrow-weed and a few similar characteristic desert plants. The average total annual rainfall for the Imperial Valley is probably less than two inches.

Geologically the Salton Basin or Sink possesses a very interesting history. We are told that in comparatively recent times, as reckoned by geologists, the Gulf of California extended northwestward to where Indio now lies. At that time the Colorado River did not flow into the head of the gulf, as now, but emptied laterally on its eastern shore at a point not far south of the present location of Yuma, Arizona. Little by little a delta was built out across the gulf, opposite the river mouth, by the vast quantities of silt carried by the river's flood waters. In time this delta spread, fan-like, until it reached and fused with the western shore of the gulf. Owing to the fact that the apex of the delta was some 40 feet above sea level, this silt deposition gradually elevated itself above sea level. The final result was that the upper (northwestern) portion of the former Gulf of California be-

came entirely cut off by the Colorado delta from the present gulf and existed, no doubt, for centuries as a large inland salt or brackish water sea with an initial area of about 2100 square miles. Eventually the sea water was displaced and the valley was occupied by fresh water.

Geologists tell us that after this stage of the formation of the Salton Basin had been reached there occurred a long succession of inundations and desiccations. Owing to the relatively steep slope or "fall" of the delta northwestward there was a constant tendency for the Colorado River to abandon its course to the gulf and break through the delta barrier to the recently formed Salton Basin. This, we are told, happened repeatedly with the result at times that the Salton Basin became filled to the level of the rim of the delta. Thereupon the river again changed its course back to its seaward channel, leaving this great inland body of water slowly to dry up through the agency of excessive evaporation. All persons who have travelled much about the present Imperial Valley have observed at various points the ancient shore line which marks the periphery of the prehistoric inland sea. Untold centuries were doubtless occupied by these alternate inundations and desiccations until, finally, man took possession of the valley and constructed barriers to prevent the further breaking in of the river.

In this manner the Imperial Valley was formed. It is easy to understand, then how it happens that the floor of the valley within the old beach lines is covered with a thick deposit of silt. Obviously, this material was carried in by the successive floodings of the Colorado River until, at present, we have the large fertile, flourishing region, reaching from a point in Mexico 20 miles south of Mexicali to Indio and from Dixieland to Holtville. Surrounding the Salton Basin on the west and north are fans of alluvial material which has been washed down from the arid mountain slopes for past ages. The transition on these two sides of the valley from silt to alluvium is very abrupt. The Salton Basin is bordered on the east by a low range of drifting sand hills. Southward the Imperial Valley opens, with practically no barriers, to the head of the Gulf of California. The former inland

sea has contracted until, in its present form Salton Sea it is 40 miles long by 15 miles wide. At its lowest point the lake bed is 287 feet below sea level.

With the settlement of the valley by man and the development and extension of the irrigation system, over 400,000 acres of the floor of the basin have been brought into cultivation. This sudden transformation from a typical desert condition to one of extreme fertility would have afforded a rare opportunity for some interesting studies in climatology and meteorology had the workers in these fields anticipated in time the revolutionary changes for which the region was destined. So far as the writer knows, unfortunately, no serious meteorological investigations had been

TABLE 1

Average monthly humidity from May, 1916, to February, 1919, inclusive

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1916					13.8	25.8	56.1	50.2	40.9	35.9	39.6	57.6
1917	64.2	40.2	27.3	27.8	27.1	27.7	46.3	41.8	37.2	35.0	31.2	37.2
1918	39.1	40.0	55.2	34.7	34.2	40.4	38.2	50.7	45.9	44.8	35.5	46.8
1919	36.1	49.6										
Average..	46.4	43.3	41.4	31.3	25.0	31.3	46.9	47.6	41.3	38.6	35.4	47.2

made in the Salton Basin previous to its settlement. The present writer has conducted observations of temperature and humidity during the period from March 1916 to the present date. Also the State Experiment Farm at Meloland and the Water Company at Calexico have at times made rather disconnected observations of a similar nature. It is to be deeply regretted that, for comparative purposes, there are available no systematic data relative to the conditions in the Imperial Valley previous to its conversion from the desert state to the cultivated condition.

The writer's meteorological data have been obtained purely incidentally to his entomological investigations, and at the outset there was no thought of employing them as in the present paper. In our contact, however, with people engaged in various

activities in the Imperial Valley we have heard an often repeated assertion, namely, that the humidity of the region is influenced directly by the use of water in irrigation. We resolved some time ago to accumulate the data necessary to test the validity of this idea, and the present deductions are based on the daily humidity readings over a period of three years together with the figures of the Imperial Irrigation District for the total use of water in the Imperial Valley by months for the identical period.

Each year in August in the Imperial Valley one hears frequent expressions concerning the alleged high relative humidity concurrent with the extreme temperatures at that time. It seems

TABLE 2

Use of water in Imperial Valley, January, 1916, to December, 1918, inclusive
Second Feet

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1916	21,942	38,071	52,664	79,720	82,737	92,187	87,363	96,066	85,515	55,670	33,814	23,438
1917	16,192	39,522	62,631	80,401	92,853	106,641	127,294	85,349	90,106	80,277	36,776	31,195
1918	33,253	39,813	57,218	100,826	118,253	111,967	135,838	134,078	122,785	78,632	40,406	34,583
Av.	23,795	39,135	57,504	86,982	97,948	103,598	116,832	105,164	99,469	71,526	36,999	29,739

to have been the almost universal opinion among valley residents that a wave of humidity strikes the region during the month of August. It is also the general belief that the maximum humidity is directly attributable to the great amount of water being used for irrigation at that time. A study of table 1 and fig. 1 will be of interest in this connection.

It will be noted in table 1 that a three-year average shows that the time of greatest humidity is in August, with the month of December a very close second.

Similarly, from table 2 it is seen that for the simultaneous three-year period the use of water in irrigating is heaviest during the month of July.

Figure 1 presents a graph visualizing the relation of the humidity to the use of water.[1] At a glance one is struck by the almost complete lack of correlation between humidity and irrigation. In January the use of water is at its lowest ebb, whereas the humidity of the atmosphere is almost at its maximum. Through February, March, April and May the use of water rapidly increases until the amount distributed over the valley in May is over four times that of January. Concurrent, however, with this greatly increased use of water it is noted that the humidity decreases fully as rapidly—from 46.4 per cent in January to 25.0 per cent in May. From May to the end of July there is a

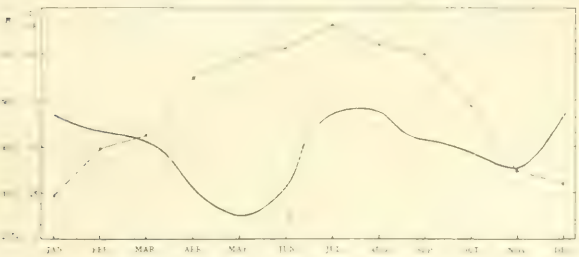

Fig. 1. Graphs showing the relation between humidity and irrigation in the Imperial Valley. Relative humidity (heavy line), three-year average, 1916–1918; use of water in thousand second-feet (light line), three year average for seasons of 1916–1918.

slight increase in the use of water amounting to about 18 per cent of the May volume. However, during the same period there is a remarkably disproportionate enhancement of humidity, amounting in July to 88 per cent in excess of the May humidity per cent. Furthermore, for our three-year period under consideration, the crest of the seasonal humidity curve was reached

[1] The humidity readings were made at El Centro with the regulation Weather Bureau sling psychrometer checked by readings on a drum hydrothermograph. The data for the use of water were furnished from the files of the Imperial Irrigation District which has complete control of all water used for irrigation in the Imperial Valley of California and Mexico.

in August but, on the other hand, July was the month of maximum irrigation. From August to November there is a considerable downward trend both of water use and humidity, but following November another remarkable discrepancy occurs. Whereas the December water distribution drops nearly to the season's minimum, the humidity simultaneously rises practically to the seasonal maximum.

From this analysis of the progress of humidity throughout the season the writer is forced to the opinion that the successive changes in the atmospheric moisture at the different periods of the year are of a geographically wide-reaching nature, and are not induced by local causes. To test the validity of this assumption it occurred to us to procure similar data for some point on the Pacific Coast outside the barrier of the Laguna Mountains.

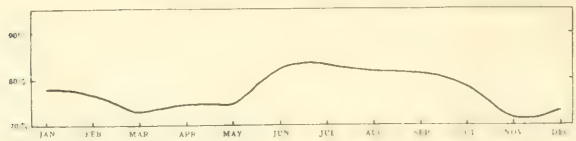

Fig. 2. Graph showing annual range of humidity at San Diego, Cal. Average for 1916–1918.

Through the courtesy of Meteorologist H. F. Alciatore, of the San Diego Weather Bureau office, we secured the humidity data for that station for the identical period of our studies in the valley.

San Diego is over 100 miles distant from El Centro and owing to the intervening mile-high range, as well as to its situation on the ocean, it might be expected to offer local conditions quite uninfluenced by Imperial Valley factors. A study of figure 2, which graphically presents the seasonal changes of humidity at San Diego, corroborates the writer's previous deductions, namely, that the year's humidity behavior in the Imperial Valley is regulated by meteorological conditions of a rather wide geographical influence. From January to May there is a somewhat general drop in the humidity, followed by a rise to the seasonal crest

through June, July, August and September. October and November witness a sharp decline followed by a substantial increase in December. In other words, there is a fairly good agreement between the seasonal humidity fluctuations for El Centro and San Diego as visualized by the charted data. Most especially we would emphasize the fact that the great increase in humidity from May to July is very evidently a regular phenomenon over an extent of territory including both the Imperial Valley and the coast region in the vicinity of San Diego.

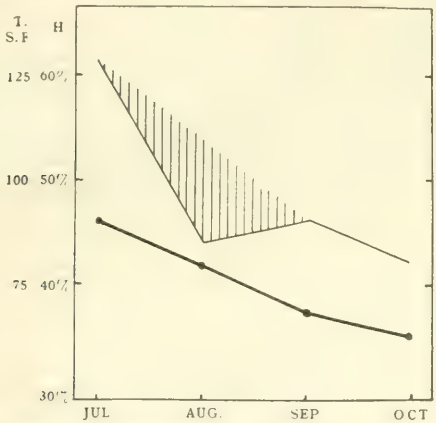

Fig. 3. Graphs showing water shortage in August, 1917, and accompanying humidity. Use of water (light line) in thousand second-feet, shortage indicated by shading. Relative humidity (heavy line) for the same months.

During August 1917 the valley suffered a rather severe water shortage through low water and engineering difficulties at the intake. During the very height of summer heat the distribution of water dropped from 127,294 second feet in July to 85,349 second feet in August, or a reduction of over 33 per cent. By referring to figure 3 it will be noted that this sudden checking of irrigation produced no apparent effect on the general seasonal trend of humidity for the same period.

By a comparison not only between the humidity and irrigation data for Imperial Valley but, in addition, between the humidity of Imperial Valley and San Diego, we believe we have demonstrated beyond question that the relative use of water at successive periods throughout the season is not a controlling factor of humidity at these respective periods. We will even go as far as to state that our studies justify the opinion that no appreciable influence upon the course of humidity through the season is exerted by the amount of irrigation water distributed over the Imperial Valley.

If our deductions are correct, therefore, we have obviously refuted the generally accepted belief throughout the Imperial Valley that the degree of atmospheric humidity is directly influenced or controlled by the relative amount of water that is distributed over the land by irrigation. And, as above stated, we are convinced that the seasonal humidity fluctuations are to be accounted for through geographically far-reaching meteorological factors.

BOOKS AND CURRENT LITERATURE

METHODS IN NUTRITION EXPERIMENTS.—A comprehensive but concise paper by Schreiner and Skinner[1] emphasizes the great value of the triangular diagram (showing the relative proportions of three constituents when the sum of all three remains the same in all cases) in fertilizer studies. A number of studies on solution cultures and sand cultures as well as on field tests, in which this system was employed, are mentioned and cited. Moreover, this paper is full of pictures and diagrams showing the authors' own devices as well as those of other writers, and these serve to illustrate the simplicity of planning nutrition experiments and presenting or interpreting the results obtained therefrom, when the triangular diagram is employed. Methods for laying out plats for fertilizer study in the field and for making fertilizer mixtures differing in salt proportions, by equal stages or increments (these being indicated by stating the fractional part—per cent—represented by each salt in the mixture), are likewise described.

In the preparation of fertilizer mixtures the authors make their calculations on the basis of equivalents of P_2O_5, NH_3, and K_2O. While there seems to be no plausible reason for adhering to this old-fashioned method—which easily leads to erroneous conceptions—yet the authors calculated their essential elements in this way so as to be "in conformity with fertilizer practice, even when the nitrogen, for instance, is in the nitrate form." There are historic reasons for the prevalence of these curious bases for calculation in fertilizer practice, but it seems desirable that the acknowledged leaders in this sort of work might soon begin to improve fertilizer practice by introducing a more logical method of calculation and comparison. It is not easy to fix upon any atomic group that will surely represent the relative nutritional value of each of the three elements, potassium, phosphorus, and nitrogen, but it is safe to say that the nutritional values of any three substances supplying these elements are surely *not* in proportion to the K, P, and N contents of these substances when these contents are calculated as K_2O, P_2O_5 and NH_3, respectively. It seems desirable to let the K, P,

[1] Schreiner, Oswald, and J. J. Skinner. The triangle system for fertilizer experiments. Amer. Soc. Agron. **10**: 225–246. 1918.

and N equivalents of a fertilizer mixture be simply represented by the actual K, P, and N contents perhaps in terms of percentages of the total weight of the mixture. It would tend greatly toward clarification of a somewhat complicated and frequently misunderstood set of relations, if this plan might be followed in field studies, just as it has generally been followed in the most satisfactory studies of water and sand cultures. If a given acre-ration of a fertilizer mixture actually contains 200 pounds of potassium there seems to be no valid reason, for calculating this amount in terms of possible K_2O many more than for calculating it in terms of possible KCl, KNO_3, K_2CO_3, K_2SO_4, or any other atomic group in which K may occur. If anyone desires to know how much of the oxide might be secured from 200 pounds of potassium, he can readily find this out, but if our fertilizer terminology were clear and direct it is doubtful if anyone would care to know the answer to such a question. If any manipulation is to be performed upon the actual content of the mixture, as represented by weight, it is immediately suggested that this ought to result in giving us the content in terms of *molecular units*, as gram-molecules, etc. But these are readily obtainable from the weight itself. As an illustration of these points, the following statements refer to the example mentioned above. The given acre-ration actually contains 200 pounds of potassium. It represents a possible 240.9 pounds of K_2O, a possible 353.2 pounds of K_2CO_3, a possible 516.9 pounds of KNO_3, etc. Finally it actually contains 2317.2 gram-molecules of potassium.

The paper here considered should be familiar to all who are interested in field experimentation on fertilizers and also to all who are interested in the salt nutrition of either plants or animals. The problems of salt nutrition are so complicated (by numerous possible variables) that a clear grasp of any concrete case is hardly to be secured without resorting to some such system of tabulation or graphical representation as that furnished by the triangular diagram for three components, or the pyramidal diagram for more than three components. Schreiner and Skinner are pioneers in the employment of this system and it is to be hoped that they, as well as others, will continue in its employment. Agricultural practice needs planned experimentation, and much of it, and this system of graphical representation permits logical planning and exhaustive interpretation of results. Ray. B. Espino.

Vegetation of Southern South America. Our knowledge of the vegetation and flora of southern Chile and the Patagonian Andes has been greatly amplified by the results of the Swedish Expedition of 1907–1909, led by Dr. Carl Skottsberg. A preliminary paper[1] published in 1910 gave an outline of the geobotanical results and a map of the distribution of the leading types of forest. In a more recent publication[2] Dr. Skottsberg has given in full the floristic and plant geographical results of the expedition. Although the botanical features of the coast itself were heretofore poorly known, we now have an extended description of the vegetation based on an overland journey of 1500 km. down the Andine valleys from Puerto Montt to Punta Arenas. The composition of the forests is given in detail and equal attention has been bestowed on the strand, bogs, swamps, alpines and savanna throughout this little-known region.

From 41° to 48° S. the coast and numerous islands are occupied by a temperate rain-forest in which about 25 evergreen broad-leaved trees are common, the most frequent being species of the antartic beech (*Nothofagus dombeyi* and *N. nitida*). This forest is rich in lianes and epiphytes as well as in ferns, including the Hymenophyllaceae. Slender climbing bamboos are abundant and epiphytic and terrestrial mosses are omnipresent, the latter sometimes reaching a height of 30 cm.

The Chilean coast from 48° S. to Cape Horn is occupied by a type of rain-forest which is low in stature, poor in number of tree species and with few lianes and epiphytes. The leading trees of this region are *Nothofagus betuloides*, *Drimys winteri* (Magnoliaceae), and the conifers *Libocedrus tetragona* and *Podocarpus nubigena*, which occur gregariously in a low forest sometimes no more than 12 to 15 feet in height. The valleys on the Patagonian side of the Andes are occupied by a deciduous forest in which the characteristic trees are *Nothofagus pumilio* and *N. antarctica*. The Patagonian "steppe" is occupied by a diversified grass-land with shrubs, root-perennials and streamside trees. The dominant grasses are species of *Festuca* and *Mulinum*, and among the shrubs are representatives of *Ephedra*, *Berberis*, *Lycium*, *Baccharis* and many other genera not so familiar to North American botanists.

[1] Skottsberg, Carl. Botanische Ergebnisse der schwedischen Expedition nach Patagonien und dem Feuerlande 1907–1909. I. Übersicht über die wichtigsten Pflanzenformationen. Kungl. Svenska Vetens. Hand. **46**; No 3: 1–28, with map. 1910.

[2] Skottsberg, Carl. Botanische Ergebnisse der swedischen Expedition nach Patagonien und dem Feuerlande 1907–1909. V. Die Vegetations-verhältnisse längs der Cordillera de los Andes S. von 41° S. br. Kungl. Svenska Vetens. Hand. **56**: No. 5: 1–366, Pls. 23. 1916.

The descriptions of both major and minor plant communities are given with fullness, and with abbreviations indicating the relative abundance of each species. An extended list of species brings together in systematic order all of the plants collected and describes their distribution and habital occurrence.

To those who are unfamiliar with a region, a much more vivid appreciation of its botanical aspects can be had from a few well-chosen illustrations than from many pages of the most carefully elaborated text. The forty-six magnificent illustrations accompanying Skottsberg's later paper, taken together with the text, and also the distributional map to be found in his earlier paper, give an extremely satisfactory first account of the plant geography of the southernmost portion of the western hemisphere. Forrest Shreve.

The Mechanism of Tumor Growth in Crowngall. As a result of further studies on abnormal proliferation of cells in plants, Erwin Smith concludes[1] that the stimuli act indirectly "by the removal of various inhibitions" rather than directly on the protoplasm of the cell. He also now believes that the agent causing proliferation is much simpler than he formerly supposed. In his experiments, castor-bean, tomato and cauliflower plants were injected with non-toxic doses of ammonia and various ammonium salts, uric, malic, tartaric, acetic, sulphuric, phosphoric, and hydrochloric acids, chloroform, sodium bicarbonate, and other substances, and the result was active cell proliferation strikingly like that of gall. It is suggested that these substances change the surface tension of the cells in the region injected, thus lessening "physiological restraint" and leading to cell division. Ammonia, as one of the metabolic products of bacteria, would saponify the lipoids of the host cell membranes, resulting in the outward diffusion of bacterial products from the invaded tissue and an inward movement of food materials necessary for rapid growth. It appears therefore, to be unnecessary to attribute the abnormal growth of galls to complex toxins. The paper includes a fine set of photomicrographs of cell proliferations in the plants subjected to experiment. J. G. Brown

[1] Smith, Erwin F. The mechanism of tumor growth in crowngall. Jour. Agric. Res. 5: 165. 1917.

NOTES AND COMMENT

Professor Douglas H. Campbell has contributed to the Stanford University Publications a paper on the Derivation of the Flora of Hawaii. He alludes to the well-known strongly endemic character of the Hawaiian flora and fauna and to the evidences for a prolonged isolation of the islands from any of the continental masses. As a result of his recent visits to Hawaii Professor Campbell has been able to increase the known flora of hepatics by 33 per cent. Among these the primitive thallose forms are the most strongly represented and all of the species are of Polynesian affinity except two that are common to that region and to North America. The evidence secured by Pilsbry in a study of Hawaiian snails corroborates the botanical evidence that the Hawaiian archipelago was formerly more extensive and connected more closely with land masses to the southwest. The sharp isolation of the islands appears to date from the early Tertiary and to have been coincident with the uplifting of the great cordillera which skirts the Pacific coast of North and South America.

Dr. W. A. Murrill, of the New York Botanical Garden, has added to his list of popular publications a small volume entitled The Natural History of Staunton, Virginia. A diary of events in the plant and animal world is given, together with lists of trees, shrubs and herbaceous plants collected in that vicinity.

Papers in the *Geographical Review* by Theodoor de Booy describe an expedition from Lake Maracaibo to the Sierra Perijá, on the frontier of Venezuela and Colombia. Both in text and illustrations these papers contain much of interest to the botanist, particularly in the descriptions of the savannas which lie west of Lake Maracaibo.

THE CLASSIFICATION OF VASCULAR PLANTS: A REVIEW

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It is no longer possible to discuss the life, structure and relationships of plants in the terminology of currently accepted classification. Professor Bower's great work on the Land Flora, issued ten years ago, and Professor Jeffrey's notable Anatomy of Woody Plants, have shed a new and clear light upon the evolution of the Vasculares. A comparison of the views so lucidly and indisputably set forth in these two epoch-making volumes with the arrangement of Engler's Syllabus or Gray's Manual shows how serious is the discrepancy between the systematic and the morphological texts. This is no criticism of the systematists. It simply means that, along major lines, systematic botany is in immediate need of revision—such a revision as constitutes the real *raison d'être* of systematists. When the evidence of a need of revision is found in two such notable texts as those of Bower and Jeffrey, the need has already become urgent, for such books are not written in a day. They represent the conclusions from many years of study and thought on the part of many workers. Such books immediately take precedence of all former work, so far at least as relates to their statement of facts.

At the same time there are details of classification and terminology on which morphological writers exhibit a freedom which might well be curbed in the interest of the botanical public. The International Rules of Botanical Nomenclature were issued in 1905 and again in 1910. But in the discussion of Gymnosperms, for example, neither Penhallow, Coulter and Chamberlain nor Jeffrey shows any apparent effort to conform to the international rules. Thus a mutual readjustment is called for. The following tabulation is an attempt at such a readjustment.

THE PLANT WORLD, VOL. 22, NO. 3
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Division 1. THALLOPHYTA. Reproduction by spores of various kinds, or by gametes, or both. No protected embryo. Plant body with little or no differentiation of vegetative organs, unicellular or multicellular.—A miscellaneous group of algae, fungi and lichens.

Division 2. EMBRYOPHYTA (Archegoniatae). Oogamic by eggs in archegonia or embryo sacs. Fertilized egg becoming a multicellular embryo, contained at first within the tissues of the parent. Alternation of generations. Plant body showing leaf and stem, and ultimately root and flower.

Subdivision 1. ATRACHEATA (Bryophyta).—Thalloid or phylloid plants of small size, without roots or tracheary tissues. Gametophyte alone lives independently, the sporophyte being parasitic upon it.

Subdivision 2. TRACHEATA (Vasculares).—Plants with root, stem and leaf containing tracheary tissues. Sporophyte lives independently of gametophyte, the latter becoming successively reduced almost to obliteration.

Series 1. LYCOPSIDA.—Palingenetically microphyllous. Tracheary tissue of stem protostelic, or siphonostelic and cladosiphonic. Sporangia few, adaxial. Leaves narrow, whorled or crowded.

Order 1. Lycopodiales
Suborder 1. Isosporineae (Isosporeae; Eligulatae)
Family 1. Lycopodiaceae
2. Psilotaceae
Suborder 2. Heterosporineae (Heterosporae; Ligulatae)
Family 3. Lepidodendraceae
4. Isoetaceae
5. Selaginellaceae

Order 2. Equisetales
Family 6. Sphenophyllaceae
7. Calamitaceae
8. Equisetaceae

Series 2. PTEROPSIDA.—Palingenetically megaphyllous. Tracheary tissue of stem protostelic, or siphonostelic and primarily phyllosiphonic. Sporangia numerous or few, primarily abaxial.

Class 1. *Aspermae*.—Fern plants, wholly lacking seed-like structures (Filicales of Gray's Manual and Jeffrey)

Subclass 1. Eusporangiatae
Order 1. Ophioglossales
Family 1. Ophioglossaceae
Order 2. Marattiales
Family 2. Asterothecaceae
3. Marattiaceae

Subclass 2. Leptosporangiatae
Order 3. Osmundales
Family 4. Osmundaceae
Order 4. Filicales
Suborder 1. Isosporineae

Family 5. Gleicheniaceae
6. Schizaeaceae
7. Matoniaceae
8. Cyatheaceae
9. Polypodiaceae
10. Hymenophyllaceae
11. Parkeriaceae
Suborder 2. Heterosporineae
Family 12. Marsiliaceae (Cf. Schizaeaceae)
13. Salviniaceae (Cf. Hymenophyllaceae)

Class 2. *Gymnospermae.*—Pollen received mostly in micropyle of ovule. No carpellary stigma. Seed bearing.

Subclass 1. Archigymnospermae.—Seeds with a pollen chamber; fertilization by motile sperms; cryptogamic wood evident.
Order 1. Cycadofilicales
2. Bennetitales
Family 1. Bennetitaceae
Order 3. Cycadales
Family 2. Cycadaceae
Order 4. Cordaitales
Family 3. Cordaitaceae
Order 5. Ginkgoales
Family 4. Ginkgoaceae

Subclass 2. Metagymnospermae.—No pollen chamber. Fertilization by means of pollen tubes. Cryptogamic wood absent or reduced to transfusion tissue.
Order 6. Coniferales (Fam. Coniferae of Eichler and morphologists)
Family 5. Pinaceae
Tribe 1. Abieteae (Abietineae of Eichler)
Subtribe 1. Pininae (Pineae of Jeffrey)
Genus 1. Prepinus
2. Pinus
3. Picea
4. Larix
5. Pseudotsuga
Subtribe 2. Abietinae (Abieteae of Jeffrey)
Genus 6. Cedrus
7. Pseudolarix
8. Abies
9. Tsuga
Tribe 2. Taxodieae (Taxodineae of Eichler)
3. Cupresseae (Cupressineae of Eichler)
Subtribe 1. Actinostrobinae
2. Thujopsidinae
3. Cupressinae
4. Junipereinae
Family 6. Araucariaceae (Araucariineae of Eichler)
7. Taxaceae

Subfamily 1. Podocarpoideae
2. Phyllocladoideae
3. Taxoideae
Tribe 1. Cephalotaxeae
2. Taxeae
Genus Torreya
Taxus

Class 3. *Angiospermae.*—Pollen received upon a stigma of the carpel
Subclass 1. Dicotyledoneae
Cohort 1. Archichlamydeae
Order 1. Casuarinales
Family 1. Casuarinaceae
Order 2. Piperales
Family 2. Saururaceae
3. Chloranthaceae
4. Piperaceae
5. Lacistemaceae
Etc., following Engler.
Cohort 2. Metachlamydeae
Order 31. Ericales
Family 189. Clethraceae
190. Pirolaceae
191. Lennoaceae
192. Ericaceae
Etc.
Subclass 2. Monocotyledoneae
Order 41. Pandanales
Family 241. Typhaceae
242. Pandanaceae
243. Sparganiaceae
Order 42. Helobiales
Family 244. Potamogetonaceae
245. Najadaceae, &c.

There should be general agreement upon the validity and significance of most of the terms of the above table. The claim that this arrangement is the most desirable one, however, may need defence. It will be possible only to suggest some of the general principles of classification to which we suppose all will agree, and to point out some of the facts upon which this arrangement is based.

A classification should first of all conform to the discovered facts of nature. Our present ideal, as I understand it, is to present in tabular form an epitome of the plant world and its

evolutionary relationships. Such a classification is a summary of all of our knowledge of plants—structure, development and life history, physiology, ecology and even bio-chemistry. For all of these are at once causes and effects of the evolutionary process. This is why classification must be ever changing, ever adjusting itself to new knowledge.

A classification must also be a convenient tool for all botanical workers. This demands simplicity. An ideal arrangement would be dichotomous. At any rate, coördinate groups must not be too numerous. There must be an adequate but not cumbrous terminology, and this must be consistently used. Groups should be monophyletic, and should be natural. Where these ideals are not compatible, which will very often be the case, it must remain a matter of opinion whether one or another principle shall prevail. On main points, however, we are now in position to expect substantial agreement.

The old distinction between Cryptogams and Phenogams is well nigh extinct. And yet it is useful for certain purposes, and should be used without apology in those cases where it is needed. There is no better means of distinguishing those plants which are disseminated primarily by spores from those which are disseminated by seeds. The distinction has become ecological rather than morphological, although of course the seed plants are descendants of spore plants. These two terms may no longer be used for elementary teaching. They belong only to peculiar situations, in the vocabulary of advanced students.

No apology is necessary for eliminating the terms endogen and exogen. One would have thought that as taxonomic divisions of seed-plants they had entirely dropped out of sight, had not a recent elementary book of considerable merit brought them again into print. *Requiescant in pace.*

It looks now as though Pteridophyta and Spermatophyta should also be committed to the history books and advanced laboratories. That the boundaries between these groups is hopelessly broken down is indicated by the fact that Engler places the Cycadofilicales in the former group, and Jeffrey places them in the latter. We could still retain these terms if

we had not something simpler, truer, and equally convenient. It is to be desired that beginning students shall approach their studies with clear, concise and accurate ideas of a permanent classification. This demands dropping a scheme which places ferns and seedplants in sharply separated primary divisions of the Plant Kingdom. So much for omissions.

The designation of Thallophyta and Embryophyta as the primary divisions of the Plant Kingdom is not all that could be desired. The lower group is far from homogeneous, and is characterized more by lack of definite organization than by any positive element. It is only in a distant way to be considered monophyletic. Engler's arrangement of these plants under eleven coördinate headings certainly has much to commend it; it is, however, too cumbrous. The gathering of these together under the single title Thallophyta does no violence to the facts. The larger unit is so convenient as to be almost indispensable in elementary work. At any rate it has found very wide acceptance and may well be retained. Under this heading the system of Engler's Syllabus, or Oltmann's Algae, or Lotsy's Lectures may be readily used. As to phylogeny, the family tree of the Vegetable Kingdom, when satisfactorily completed, will most resemble the classic hour-glass-shaped pasture-form of thorn tree—from a broad bushy base, representing the lower plants, will arise a fairly clean cut trunk, which again branches above into the broad and bushy crown of the Embryophyta. The unity of this latter group is attested by the widely accepted name of Archegoniatae. We have preferred the newer name for three reasons. First the occurrence of an embryo developed from the fertilized egg and cared for during its early stages within parental tissues, is an outstanding character of the group, and it is this character which has probably been a determining factor in the survival and extension of the group. The statement in Gray's Manual, p. 33, that ferns are without embryo refers only to the product of the spore. Secondly, the archegonium is at best a small and obscure organ, not easily seen or appreciated; and it is completely obliterated in the higher members of the series. Finally, according to the euphony or terminology, if you like

so popular in botanical nomenclature, the words Embryophyta and Thallophyta readily suggest one another.

The division of Embryophyta into those groups without tracheary cells and those with such organs may be opposed because it involves a negative character. On the other hand, the Vascular plants have long been recognized as a group with profound natural affinities. This distinction, used by De Candolle over a hundred years ago, was powerfully reasserted by de Bary's anatomical treatment of the group. It is rendered permanent and unequivocal by the critical researches and logical analysis of Professor Jeffrey and his school. There is nowhere a more "natural" unit than the Tracheata and the tracheary tissues which have been used to prove this fact may well be referred to in naming the group. The term Vasculares, referring to vessels, is not so apt, seeing that true vessels are absent in a large portion of the group.

The most brilliant achievement of inductive reasoning since the days of Hofmeister was the recognition by Jeffrey in 1898 of the two great phyla of tracheate plants, the Lycopsida and Pteropsida. This distinction has been freshly vindicated by every discovery bearing on the problem. The fundamental differences in stem, leaf, and sporangium between these two phyla are absolutely basic to any discussion of the broader aspects of comparative anatomy of vascular plants.

It will be readily recalled that in all Lycopods and Equiseta the leaves are very small (microphyllous). The sporangia of *Lycopodium*, *Selaginella* and *Isoetes* are clearly related to the upper surface of the leaf (adaxial). In *Equisetum* the sporangiophores are the relics of an axillary or dorsal outgrowth of the sporophyll. The sporophyll has entirely disappeared from living Equiseta. The leaf trace of *Equisetum* is small, and its separation from the vascular system of the stem makes no gap or other modification in the latter. A similar condition exists in Lycopodiales. But in those Lycopodiales with a hollow cylinder of vascular tissues, this cylinder is interrupted or broken open by the passage of a segment of it, entire, out into a branch (cladosiphonic).

On the other hand, the leaves of ferns and angiosperms and the older Cordaitales and Cycadales, are usually large and conspicuous (megaphyllous). Small leaves are in all cases clearly modifications of the former type. The sporangia in nearly all the lower forms are numerous, and on the back of the leaf (abaxial). Profound modifications of this character occur in Angiosperms. Wherever a leaf is attached to the stem in all of this great group of plants, the vascular tissues of the stem bend out bodily to form the leaf trace. In hollow cylindrical vascular systems, this leaves a gap in the cylinder—a leaf gap (phyllosiphonic).

In view of the importance of these distinctions, it is imperative that at this point, at least, classification must be immediately adjusted to the present morphological conclusions. And if the profoundest cleavage in the higher plants lies between the Lycopsida and Pteropsida, then we must put into the background such terms as Pteridophyta and Spermatophyta. Nothing may be permitted to obscure this major conclusion.

In our present imperfect knowledge of the fossil Tracheata, we are unable to separate sharply between the fern-like seed plants and the seed-plant-like ferns. Apparently this separation is destined to become more obscure with increasing knowledge. We are therefore justified in co-ordinating the ferns and gymnosperms. The evidence tends also to close the gap between gymnosperms and angiosperms. There are left, therefore, in the Pteropsida three co-ordinate groups. The nomenclature of these groups and their subdivisions presents some awkward difficulties.

According to International Rules, groups of ordinal rank have names ending in *-ales*. Names of sub-orders end in *-ineae*, of families in *-aceae*, of sub-families in *-oideae*, of tribes in *-eae*, and of sub-tribes in *-inae*. This has become current usage in the classification of angiosperms. The results are so satisfactory that the terms have met with general acceptance, and there is even a surprising unanimity regarding the limits and contents of the many orders and families. It would obviously be folly to criticise or attempt to change this usage as applied to dicoty-

ledons and monocotyledons. Similarly, in the Lycopsida, the names of orders and families are practically fixed. The basis, at least, is agreed upon. It must be noted, however, that the orders in Lycopsida are very much more distinct from one another than are the orders of dicots and monocots. The termination *-ales* is consistently used within each great group, but is not used consistently when the two great groups are compared. This is due to the one group being small and nearing extinction, and the other being large and aggressive. The inconsistency is not objectionable, and is almost unavoidable.

It seems necessary, for the sake of uniformity to adopt the sub-ordinal names Isosporineae and Heterosporineae in place of the more common Isosporeae or Isosporae and Heterosporeae, both in lycopods and ferns.

The ordinal grouping of ferns presents a somewhat difficult problem. The second and third groups of Pteropsida are named Gymnospermae and Angiospermae, each group being divided into orders with names ending in *-ales*. The first or fern group of pteropsidans therefore cannot properly be called Filicales. But this is the term used by Gray's Manual, and by Jeffrey throughout his Anatomy of Woody Plants. Engler recognizes in the fern alliance three orders: Filicales leptosporangiatae, Marattiales, and Ophioglossales. Coulter, in the Chicago text book, recognizes only Ophioglossales and Filicales. Now the usage of the Harvard systematists may be explained on the basis of a group consisting of but one order, viz. Filicales, including all the families from Ophioglossaceae to Salviniaceae. Even in this case there is need for another term to stand co-ordinate with Angiospermae and Gymnospermae. This term might be Filices. For the sake of euphony, however, we have proposed the name Aspermae for this group. The term also signifies the real distinguishing character on which the divisions of Pteropsida are based in this case, the absence of seeds. The "alpha privative" occurs also in the term Atracheata, and in many other modern scientific terms; it is in good repute. The Aspermae may then include but one order, Filicales, if desired, in which case Aspermae is practically synonymous with Filicales. Or,

Aspermae may be divided into two, three, or four orders. In view of the antiquity of the Osmundaceae, their evolutionary history, and the manner of development of root tip and sporangium, this group would seem to have as good a right to ordinal rank as the Ophioglossales or Marattiales. We would favor therefore dividing Aspermae into four orders, or leaving it as a single order Filicales. The small aberrant group of hetersporous forms may not be natural or monophyletic; it may remain, however, pending a conclusion.

Among Gymnosperms a similar confusion of terms has arisen. If it be accepted, as it seems to be, that every plant, beside belonging to a certain species and genus, must be assigned to a certain family and order we will have a basis for action. For example, the single living species of ginkgo tree is named *Ginkgo biloba*, of the family Ginkgoaceae and order Ginkgoales—a monotypic order. What becomes of the old Coniferae? Naturally they become the order Coniferales. If this order is believed to contain but one family, that family may be called Coniferae, being a special case, in company with Cruciferae, Leguminosae and Compositae. If there are two or more families in the group, they would be the Pinaceae and Taxaceae of Lindley, with a possible Araucariaceae. But these as well as their further subdivisions have been variously named by leading American authorities. Penhallow names Taxoideae as an *order* of the *class* Coniferales; Coniferae as a second *order*, with Cupressineae, Abietineae, Pinoideae, etc., as *families*. Such terminology is impossible for the taxonomist, and confusing to the general student. Coulter and Chamberlain recognize two families in the order Coniferales: Pinaceae and Taxaceae. The former is divided into tribes Abietineae, Taxodineae, etc. Jeffrey speaks of the Coniferales as a unit group, with tribes Abietineae, Cupressineae, Araucariineae, Taxineae, etc. He further divides Abietineae into Pineae and Abieteae. Obviously these eminent authorities have followed Eichler's treatment in the Natürlichen Pflanzenfamilien of 1889 instead of conforming to the International Rules of Nomenclature. It is therefore with considerable difficulty that one digs out from their works the

taxonomic significance of their invaluable contributions to our knowledge.

In summary it would seem that we have the systematic group or *order* Coniferales, containing one *family*, Coniferae, according to Eichler and Jeffrey; or two families, Pinaceae and Taxaceae, according to Coulter and Chamberlain, and Engler's Syllabus; or nine families according to Penhallow. Certain it is that the Taxaceae are so distinct from the Pinaceae in many ways that the difference is almost universally accepted as of family rank. It will be most helpful so to consider it. It would seem wise to separate also the kauris and their kin under the caption Araucariaceae. This group is almost as aberrant as the yew family, and much more homogeneous. It has been distinct since the Jurassic or earlier, and has evolved along its own lines independent of the other two families but parallel with them.

The terminology of the subdivisions of Pinaceae should be corrected in the interest of the general student and in harmony with international usage. Thus the rich library of fact and thought included in the books above quoted, may the sooner be disseminated into the most widely used texts, and become the common possession of botanists everywhere. No hindrance should stand in the way of this desired end.

There remains a question as to whether Jeffrey's division of Archigymnospermae and Metagymnospermae is the most helpful that could be devised at that point. From the standpoint of seed structure, fertilization, and cryptogamic wood this distinction is of first importance. But it throws a strong division between the Ginkgoales and Coniferales, which, on the basis of stem anatomy, are very near of kin. It may ultimately prove more helpful to distinguish between the Cycadean phylum with its pithy stems and broad rays, and the Cordaitean phylum with its small pith and primitively uniseriate rays.

The slight modifications suggested above in the terminology used by morphologists, and in the expression of family relationship as used by systematists can easily be slipped into the existing texts by intelligent readers and teachers. To the beginner, the new classification is just as acceptable as the old. The beginner

has no prejudices or preconceptions. And once learned, the plan which is at once simplest and truest must prove easiest and most helpful. It would be of inestimable value to have all the rising generation of students come forward free from the trammels of an old fashioned sequence and terminology. The student should have as little as possible to unlearn. All who have reached middle age realize how much of our life is spent in unlearning. This is a necessary function, but it should be exercised as little as possible.

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THE FLORA OF THE PINE BELT OF THE SAN ANTONIO MOUNTAINS OF SOUTHERN CALIFORNIA

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(To be continued)

The San Gabriel Mountains are a well defined division of the southern extension of the Sierra Nevada Range. With the exception of the extreme eastern portion, they lie wholly within the boundaries of Los Angeles County, California, and stretch their sixty miles of length as a barrier between the Mojave Desert to their north, and the cooler coastal plain to their south.

These mountains are composed of granitic rock and are extremely rugged. The sharp peaks, narrow ridges, talus slides and deep labyrinthine cañon are the most conspicuous features of the San Gabriel Mountains. Their cañon are evenly graded and in most cases have fair sized streams. Occasionally one finds small hillside marshes, but the lakes and large cienegas, which are important features in the neighboring San Bernardino and San Jacinto Mountains, are conspicuously lacking. There are a few rich moist slopes, but due, perhaps, to the porous character of the soil, the majority of the ridges are very dry, even on their north slopes.

The sky line for the most of its length averages about 7000 feet altitude, but at the eastern end, on the Los Angeles-San Bernardino county line, it reaches a maximum altitude of 10,080 feet on the summit of Mt. San Antonio (or Old Baldy). This eastern section, a very natural subdivision of the San Gabriel Mountains, has been called the San Antonio Mountains. They can best be limited as that portion of the San Gabriel Mountains which lies east of the bed of the East Fork of San Gabriel River.

The area,[1] thus defined, is triangular in shape and contains approximately 150 square miles. Mt. San Antonio, or Baldy as we shall call it hereafter, is of especial interest, for besides being the highest peak in the San Gabriel Mountains, it is one of the four peaks in Southern California which ascends above the 10,000 foot contour. Connected to Baldy by pine clad ridges, which average over 7500 feet altitude, are a number of lesser peaks. These are.—Pine Mountain (alt. 9660 feet), Telegraph Peak (alt. 9008 feet), Cucamonga Peak (alt. 8911 feet), Ontario Peak (alt. 8752 feet) and Iron or Sheep Mountain (alt. 8028 feet).

The San Antonio Mountains have been explored by all the well known botanists of Southern California. The first to visit the mountains was Mr. S. B. Parish, who ascended them in 1880. Prof. A. J. McClatchie was the next visitor, who collected on Baldy in August, 1893. During the successive springs of 1899 and 1900 Dr. H. M. Hall explored and made collections on the northern base of the mountains. In July of 1901 and 1902 Dr. LeRoy Abrams visited Baldy Summit and in the summer of 1908, accompanied by Mr. E. A. McGregor, he collected in Swartout Valley and Lone Pine Cañon. Several other persons have made collections in the San Antonio Mountains, among whom are.—Mr. J. B. Leiberg, Mrs. Charlotte M. Wilder and Mr. Fred Burlew. It is interesting to note, that with the exception of Professor McClatchie and Mrs. Wilder, all the collectors worked on the north side of the mountain. The most of the collecting seems to have been done along the so-called, "Glen Ranch Trail to Baldy." Although the mountains have had a number of visitors they have had by no means a thorough botanical exploration. The visitors have made but hurried dashes into the more accessible parts, covering the same ground as their predecessors, and spending in the pine belt only a day or two. Realizing that much of the mountain was either untouched or very imperfectly known we planned and made a series of ten collecting trips into the pine belt. These trips, which were made during the spring and sum-

[1] The San Antonio Mountains have been mapped by the government and are to be found on the San Antonio and Cucamonga topographical quadrangles of the U. S. G. S.

mer of 1917 and 1918, total twenty-nine days; on them we visited all the cañons and peaks with the exception only of Swartout Valley and Lone Pine Cañon. These two cañons were not visited because of lack of time. However, thanks to the efforts of Dr. Hall and Dr. Abrams, they are the best known parts of the San Antonio Mountains.

The only literature dealing in any way with the San Antonio Mountains is Dr. Abrams' Flora of Los Angeles and Vicinity,[2] which has a range so defined as to include the coastal slopes.

Fig. 1. Mount San Antonio as seen from the summit of Ontario Peak

While fairly satisfactory in the Upper Sonoran Zone, it was found to be of little or no value in the pine belt, a fact not surprising if one remembers that our knowledge of the south slope has been obtained by two hurried collectors.

The San Gabriel Mountains are one of the least known of the Southern California group, a fact which is very apparent if they

[2] Abrams, LeRoy. Flora of Los Angeles and Vicinity. Stanford University, Calif. April, 1917. Pp. 1–402.

are compared with the San Jacinto[3] or San Bernardino[4] Mountains. The writer hopes that the following paper, while only dealing with a limited portion of the San Gabriel Mountains, will be a contribution towards the desired knowledge of their flora.

Three life zones are distinguishable in the San Antonio Mountains: the Upper Sonoran, Transition and Canadian. The Upper Sonoran Zone includes the bases of the mountains, never ascending higher than 6000 feet altitude. This zone is recognized at once by the presence of dense thickets of shrubs, called chaparral, which cover the mountain side. The chaparral belt does not have its twenty-five or more component shrubs in an unvarying mixture, for not only are some species restricted geographically, but on the coastal slope, in response to differences in moisture and temperature, two distinguishable life belts have been formed within the chaparral belt. These are hereafter designated as the "Upper" and "Lower Chaparral Belt." The Lower Chaparral Belt is characterized by the dominance of such shrubs as, *Adenostoma fasciculatum*, *Quercus dumosa* and *Ceanothus crassifolius*. On south facing slopes these plants grow abundantly below 4500 feet altitude, on north slopes they seldom reach an altitude of 3000 feet. The Upper Chaparral Belt, on the other hand, is found usually above the 4500 feet contour on south slopes, and never lower than 3000 feet on north facing slopes. *Arctostaphylos tomentosa*, *Quercus Wislizeni* and *Ceanothus divaricatus* are the dominant shrubs in the Upper Chaparral Belt.

Since we have not visited the desert base of the mountains we are unable to discuss its Upper Sonoran flora. Because of this fact and because the composition of the chaparral is well known and similar to that found in adjacent territory we have not included the chaparral flora in the catalogue which forms the bulk of this paper.

[3] Hall, H. M. A Botanical Survey of the San Jacinto Mountains. Univ. Cal. Pub. Bot. 1: 1–140, 1902.

[4] Parish, S. B. An Enumeration of the Pteridophytes and Spermatophytes of the San Bernardino Mountains, California. Plant World 20: 163–178; 208–223 and 245–259, 1917.

The Transition Zone, usually found between 5500 and 8000 feet altitude, is for all practical purposes coincident with the occurrence of *Pinus ponderosa* and its variety *Jeffreyi*. The Transition, like the Upper Sonoran Zone, has been conveniently divided into two parts. The upper, which usually lies above 6750 feet altitude, has been designated as the Upper Transition Zone and is characterized by the dominance of *Abies concolor* and *Pinus Lambertiana*. To the lower part, where typical *Pinus ponderosa* is most abundant, the name Lower Transition Zone has been

Fig. 2. A forested slope in the Canadian Zone, on the south spur of Baldy at about 9000 feet altitude

applied. The following list of perennials appear to be restricted to the designated divisions of the Transition Zone.

Plants restricted to the Lower Transition Zone	*Plants restricted to the Upper Transition Zone*
Sitanion minus californium	*Sisyrinchium oreophilum*
Eriogonum umbellatum	*Carex aurea celsa*
Lupinus Grayi	*Salix cordata Watsoni*
Arctostaphylos Parryana	*Eriogonum Wrightii subscaposum*
Chænactis santolinoides	*Arabis repanda*
Brickellia microphylla	*Adenostegia Nevinii*
	Sambucus glauca velutina

A large number of plants which are confined to the Transition Zone seem to range throughout the zone irrespective of subzones. Among these are,—

Plants ranging throughout the Transition Zone

Pellæa Wrightiana californica	*Ribes nevadensis*
Phoradendron paucifolium	*Prunus demissa*
Eriogonum nudum	*Ceanothus cordulatus*
Eriogonum molestum Davidsonii	*Pyrola pallida*
Dudleya pumila	*Gilia latiflora exilis*
Silene verecunda platyota	*Helenium Bigelovii*

The great majority of plants usually extends up into the Canadian Zone or down into the Upper Sonoran Zone. The more conspicuous examples of these are given in the following lists.

Plants common to the Transition and Upper Sonoran Zones

Pteris aquilina lanuginosa	*Quercus chrysolepis*
Cheilanthes Fendleri	*Eriogonum fasciculatum polifolium*
Cystopteris fragilis	*Aquilegia truncata*
Pseudotsuga macrocarpa	*Clematis ligusticifolia*
Bromus grandis	*Viola purpurea pinetorum*
Carex alma	*Brickellia californica*
Populus trichocarpa	*Solidago californica*

Plants common to the Transition and Canadian Zones

Sitanion minus	*Ribes cereum*
Carex brevipes	*Scriocotheca concolor*
Allium Breweri	*Drudeophytum vestitum*
Allium Burlewii	*Arctostaphylos patula*
Salix flavescens	*Gilia pungens tenuiloba*
Castanopsis sempervirens	*Monardella cinerea*
Eriogonum saxatile	*Boschniakia strobilacea*
Silene Parishii	*Hieracium horridum*
Arabis platysperma	*Symphoricarpus Parishii*

The composition of the Transition flora is somewhat different on the two sides of the mountain. The most conspicuous difference is the absolute lack of *Ceanothus cordulatus*, *Artemisia tridentata* and *Tetradymia canescens* on the south or coastal side. On the desert side these three are the most common shrubs. There are a number of plants which, while present on the south side, are very much less frequent there than they are on the

north side. This list includes,—*Prunus demissa*, *Fremontia californica*, *Gayophytum caesium*, *Castilleja miniata*, and *Chrysothamnus nauseosus*. The south side of the mountain is strikingly lacking in plants which are peculiar to it.

The Canadian Zone, in the San Antonio Mountains, is characterized by *Pinus Murrayana* and *Draba corrugata*. It includes most of the mountain above 8000 feet altitude, embracing an area of about ten square miles. The largest part of the zone consists of bare exposed ridges, but there are, in a few scattered spots, small protected areas which bear a Canadian Zone flora. No water is found within the Canadian Zone and hence the flora is somewhat limited.

Plants restricted to the Canadian Zone

Pinus Murrayana
Carex abrupta
Calyptridium Parryi
Arenaria Nuttallii gracilis
Draba corrugata
Ribes montigenum
Heuchera Abramsii
Galium multiflorum parvifolium
Erigeron jacinteus
Crepis nana

Since the flora of the summit of Mt. San Antonio may be of interest the following list is given, which includes those plants growing between 10,000 and 10,080 ft. altitude, or those growing within about fifty yards of the summit cairn.

Summit flora of Mt. San Antonio (10,000–10,080 ft.)

Pinus Murrayana
Sitanion minus
Carex abrupta
Carex brevipes
Allium Breweri
Castanopsis sempervirens
Eriogonum umbellatum minus
Eriogonum saxatile
Arabis platysperma
Draba corrugata
Heuchera Abramsii
Ribes montigenum
Ribes cereum
Sericotheca concolor
Viola purpurea pinetorum
Drudeophytum vestitum
Gilia pungens tenuiloba
Collinsia Torreyi Wrightii
Galium multiflorum parvifolium

CATALOGUE OF THE VASCULAR FLORA OF THE PINE BELT

The following catalogue is founded mainly on collections made by the author. A number of species have been collected in the San Antonio Mountains by others which the writer failed to discover. In such cases, if the specimen was seen, the record was

incorporated into the catalogue along with the name of the collector and the number of the collection. If the specimens forming the basis of record were not available for study then the published record was copied *verbatim* and its location given. Our list, thus formed, now includes 315 species and varieties of native plants. Introduced plants, which number about 20, have not been included in the catalogue.

Many notes on distribution, abundance and habitats were made during our exploration of the mountains. These notes, supplemented by less extensive ones made previous to 1917, form the basis for the discussion under each species treated. The discussions of systematic relationships are the outcome of a careful study of herbarium material and of much time spent over the taxonomic literature. It is perhaps unnecessary to state that all statements concerning distribution, etc. are founded on, and concern only, the species as it occurs in the San Antonio Mountains. In a majority of cases the habitat, zonal distribution and abundance is the same as it is in the San Bernardino or San Jacinto Mountains but this, however, is not always the case.

For invaluable help in the preparation of this paper the author is under especial obligations to Mr. S. B. Parish of San Bernardino. His help in taxonomic difficulties, his suggestions and kindly criticisms all warrant the writer's sincere gratitude. To Dr. H. M. Hall of the University of California we are also much indebted for his courtesy and interest, and especially for the privileges granted us while working in the herbarium under his charge. We wish to acknowledge of the help of several other taxonomists, among whom are Mrs. Agnes Chase, Dr. J. M. Greenman, Dr. W. L. Jepson, Prof. M. E. Jones, Mr. J. F. Macbride, Mr. K. K. Mackenzie, Mr. W. R. Maxon, Dr. B. L. Robinson, Dr. J. N. Rose, Dr. P. A. Rydberg, Mr. Camillo Schneider and Mr. G. P. Van Eseltine.

OPHIOGLOSSACEÆ

Botrychium lunaria (L.) Swz. Not uncommon in springy ground near 7000 ft. alt. in Coldwater Fork Lytle Creek. Here in the Upper Transition Zone it grows with *Lemmonia* [illegible], *Trisetum* [illegible], *Carex aurea celsa* and *C. subfusca*. The plant does not grow in the mucky part of the marsh but seems to grow in the better drained portions near its head. Det. W. R. Maxon. (No. 1358, 1757, 2080.)

POLYPODIACEÆ

Pteris aquilegia L. var. *lanuginosa* Hook. Common in springy ground in both the Upper Sonoran and Transition Zones. (No. 1617.)

Cheilanthes Fendleri Hook. In rock crevices throughout the Transition Zone reaching an altitude of 8500 ft. on Ontario Peak. The plant is much more common in the Upper Chaparral Belt. (Nos. 1594, 1729.)

Pellæa Wrightiana Hook var. *californica* Lemmon. Frequent in dry rocky ground in the Transition Zone. (No. 1593.)

Aspidium rigidum Swartz. var. *argutum* (Kaulf.) Eaton. Very common on cool shaded cañon sides in the Lower Chaparral Belt. Less common in the Upper Chaparral Belt, from which it occasionally extends into the Lower Transition Zone. Seen as high as 6500 ft. alt.

Polystichum munitum (Kaulf.) Underw. Moist cool shaded cañons in the Upper Chaparral Belt and occasionally in the Lower Transition Zone. Reaching 7000 ft. alt.

Cystopteris fragilis Bernh. Very moist situations, as rock crevices by waterfalls or wet ground on stream banks. Seen at 8250 ft. alt. on the upper edge of Transition Zone. Common in the Upper Chaparral Belt. (No. 1619.)

EQUISETACEÆ

Equisetum Funstoni A. A. Eaton. Occasional along streams in the Transition Zone. Reaching 7000 ft. alt. (No. 1723.)

SELAGINELLACEÆ

Selaginella Bigelovii Underw. A very common Upper Sonoran species which ascends to the lower levels of the Transition Zone. Collected at 6000 ft. alt. on the west end of Ontario Peak. (No. 1827.)

Selaginella sp. A selaginella, apparently an undescribed species, is frequent among rocks throughout the Transition Zone. Especially abundant on Ontario Peak, the west end in particular, where it not infrequently carpets the ground. Usually growing with *Dudleya pumila*. Ranging from 4300 to 8500 ft. alt. (Nos. 1595, 1807, 1815.)

PINACEÆ

Pinus Lambertiana Dougl. Very common in the fir forests of the Upper Transition Zone. Not seen lower than 5500 ft. alt.

Pinus monophylla Torr. & Frem. A large colony at 6500 ft. alt. in the lower part of the Transition Zone in the upper part of North Fork Lytle Creek. Common at lower altitudes on the desert base of the mountains. (No. 1722.)

Pinus Murrayana Balfour. The common and characteristic pine of the Canadian Zone. Seen as low as 8000 ft., but usually appearing at about 8500 ft. alt. The only tree on Baldy Summit. (No. 1625.)

Pinus ponderosa Dougl. The characteristic pine of the Transition Zone; most common in its typical form below 6000 ft. alt.

Pinus ponderosa Dougl. var. *Jeffreyi* (Murray) Vasey. Common in the Upper Transition Zone.

It has often been pointed out that this variety and the species are at times difficult to separate, a condition found to be very true in the San Antonio Mountains. We always found trees at about the middle of the Transition Zone which defied all attempts at placing them, despite the fact that we used all the characters of bark, cones, foliage and seeds. The characters given to the variety and those given to the species were found to be manifested in a bewildering series of combinations which made the definite placing of these trees an absolute impossibility. While we admit that the yellow pine found on the ridges in the Upper Transition Zone is a fair variety of the yellow pine which grows in the cañons in the Lower Transition, we are inclined to think, that in the light of the complete gradation of the one into the other, that perhaps the rank of "form" would better indicate the true relationship of the Upper Transition plant to typical *P. ponderosa*, at least in Southern California.

Pseudotsuga macrocarpa (Torr.) Mayr. Frequent in the Upper Chaparral Belt and Lower Transition Zone. It grows as low as the mouth of San Antonio Cañon, alt. 2000 ft. and as high as 7000 ft. alt. in Icehouse Cañon.

Abies concolor Lindl. & Gord. Common in the Upper Transition Zone, where it is the dominant tree.

CUPRESSACEÆ

Libocedrus decurrens Torr. General throughout the Transition Zone but not very common. In the lower part of the zone it is found wholly in moist cañons or on streams banks, but in the upper part it is often found growing on talus slopes or rocky mountain sides with fir and pine. Occasional trees are found in moist situations in the chaparral belt descending as low as 2700 ft. alt. (No. 1624.)

Juniperus occidentalis Hook. One of the less common trees. In our mountains the tree grows only in the Upper Transition Zone. The scattered colonies have been found between 8000 ft. (Old Gold Ridge Mine) and 9660 ft. alt. (Pine Mt. Summit). (Nos. 1400, 1623.)

GNETACEÆ

Ephedra viridis Coville. A large colony on a dry, sunny hillside, alt. 5000 ft., in Prairie Fork San Gabriel River. This station is on the lower edge of the Transition Zone. Frequent on the desert base of the mountains. (No. 1721.)

GRAMINEÆ

Stipa occidentalis Thurb. Not uncommon in bare rocky slopes in the Upper Transition and Canadian Zones. (Nos. 1504, 1537.)

Stipa Parishii Vasey. Throughout the Transition Zone, chiefly on gravelly cañon floors. Apparently most abundant on the north side of the mountains. (No. 1515.)

Muhlenbergia californica Vasey. Moist ground on a sunny cañonside, Upper Transition Zone, in Coldwater Fork Lytle Creek, alt. 7000 ft. Common in the chaparral belt, especially in rock crevices wet by seepage. (No. 1629.)

Muhlenbergia squarrosa Trin. Rydb. Wet ground in the Upper Transition Zone. Icehouse Cañon, alt. 6500 ft. Upper San Antonio Cañon, alt. 7350 ft. Coldwater Fork Lytle Creek, alt. 7000 ft. (Nos. 1506, 1628.)

Epicampes rigens Benth. On the lower edge of the Transition Zone in Prairie Fork, alt. 4750 ft.

Agrostis exarata Trin. Occasional along streams in the chaparral belt from which it ascends into the lower part of the Transition Zone. 5500 ft. alt. in Upper San Antonio Cañon. (No. 1509.)

Agrostis Rossae Vasey. Springy ground in the Upper Transition Zone. Old Gold Ridge Mine at 8000 ft. and at 7000 ft. alt. in a small side-cañon of Prairie Fork. (Nos. 1510, 1634.)

Agrostis idahoensis Nash. Abundant around the waterhole at Kellys Cabin on the upper edge of the Transition Zone. (No. 1522.)

Koeleria cristata (L.) Pers. Occasional in the Transition Zone; much commoner at lower levels. (Nos. 1453, 1520, 1521.)

Melica stricta Bolander. Common in rocky ground in the Upper Transition Zone on the north side of the mountains. Not detected on the south side. (Nos. 1501, 1516, 2065.)

Poa scabrella (Thurb.) Benth. Common in dry ground in the chaparral belt and in the Transition Zone. (No. 1355.)

Bromus Orcuttianus Vasey var. *Hallii* Hitchc. Lower Transition Zone in Prairie Fork San Gabriel River, 6000–7000 ft. alt. and at 6000 ft. in the South Fork Lytle Creek. (Nos. 1454, 2070.)

Bromus carinatus H. & A. Not uncommon in dry ground in the Lower Transition Zone.

Bromus grandis (Shear) Hitchc. Frequent in dry ground throughout the chaparral belt and the Transition Zone. (No. 1407.)

Agropyron tenerum Vasey. Common in moist ground in the Upper Transition Zone. (Nos. 1512, 1630 part, 2069.)

Agropyron caninum (L.) Beauv. Common on Browns Flats and also at several stations in Upper San Antonio Cañon. Lower Transition Zone. (No. 1518.)

Elymus glaucus Buckl. Common in dry ground in the Chaparral Belt and in the Transition Zone. (Nos. 1296, 1498, 1517, 1630.)

Sitanion minus J. G. Smith (*S. rigidum* J. G. Smith). Common in dry rocky ground in the higher parts of the Transition and throughout the Canadian Zone.

We are following Hitchcock (Jeps. Fl. Cal. 188.) in merging *S. rigidum* into *S. minus*. We consider both species to be nothing more than reduced ecological forms due to subalpine and desert conditions. (Nos. 1497, 1499, 1523, 1635, 1638.)

Sitanion minus J. G. Smith var. *californicum* (J. G. Smith) Johnston comb. nov. (*S. californicum* J. G. Smith, *S. glabrum* J. G. Smith.) Frequent under the pines in the Lower Transition Zone. Occasional in the Upper Chaparral Belt.

Careful observation of this plant in the field has convinced us that it has no right to the rank of species. Numerous times we have observed it grade into *S. minus* as we ascended the mountains. The greater size, the only character which separates this plant from *S. minus*, is undoubtedly due to its more favorable habitat, and hence is a very poor character for a species.

We do not believe that *S. californicum* and *S. glabrum* can be maintained distinct. In the field it was found that they were connected by a good series of intermediate forms. Smith (U. S. Dept. Agr. Div. Agrost. Bull. 18: 9), followed by Abrams (Fl. Los Ang. 57. 1917), separates *S. glabrum* from *S. californicum* by its glabrous culms, leaves and sheaths. We found so much variation in pubescence that we are unwilling to use the character or amount of pubescence as a specific or even varietal character. Hitchcock (Jeps. Fl. Cal. 187) separates the two plants by assigning to *S. californicum* entire glumes and to *S. glabrum* bifid or occasional bifid glumes. This means of separating the two plants is even less satisfactory than the presence or lack of pubescence. As would be expected, there is no sharp line between plants having "glumes entire" and those having "glumes, or some of them, bifid." As an extreme case we can mention a plant collected at the mouth of North Fork San Antonio Cañon which after a careful dissection proved to represent both species! Of the six heads on the plant two of them had all the glumes entire while the rest had the "glumes, or some of them, bifid"! (Nos. 1304, 1500.)

CYPERACEÆ

Scirpus microcarpus Presl. Frequent in marshy ground in the chaparral belt; rare in the pine belt, where it is confined to the lower most portions.

Eleocharis montana R.& S. Moist ground at Native Son Mine, alt. 5000 ft. Lower Transition Zone. (No. 1631.)

Carex (*Primocarex*) *multicaulis* Bailey. Occasional under the pines but much more abundant on moist shaded cañon sides in the Upper Chaparral Belt. (No. 1426.)

Carex (*Eucarex*) *aurea* Nutt. var. *celsa* Bailey. (*C. Hassei* Bailey.) Abundant in springy ground throughout the Upper Transition Zone. Always growing with *Sisyrinchium*. 6000-8250 ft. alt. (Nos. 1391, 1413.)

Carex (*Eucarex*) *buxipes* W. Boott. Found in varying quantities from the uppermost portions of the Transition Zone to Baldy Summit. Usually growing in large patches on dry ground under the pines but on Baldy Summit it grows in the shelter of rocks. Most abundant in the region centering about Kellys Cabin. Determined by Mr. K. K. Mackenzie. (No. 1496.)

Carex (*Vignea*) *aquatilodes* Mackenzie. Common in springy ground in the upper parts of Icehouse Cañon. A few plants were collected at 7000 ft. alt in Coldwater Fork Lytle Creek. Both stations are in the Upper Transition Zone. Det. K. K. Mackenzie. (Nos. 1505, 2005.)

Carex (*Vignea*) *subfusca* W. Boott. Coldwater Fork Lytle Creek, alt. 7000 ft.; side-cañon of Prairie Fork, alt. 7000 ft.; Kellys Cabin, alt. 8250 ft. Locally abundant at all three stations all of which are in the Upper Transition Zone. (Nos. 1393, 1503.)

Carex (*Vignea*) *alma* Bailey. Frequent in moist ground in the Upper Sonoran and Transition Zones. (Nos. 1411, 1508, 2061.)

Carex (*Vignea*) *abscapta* Mackenzie. Common on Baldy Summit; very abundant on Pine Mountain. On the latter peak it grows so thick that some patches resemble a field of grain. The plant grows in dry rocky ground and seems to be confined to the higher parts of the Canadian Zone. (Nos. 1399, 1636.)

JUNCACEÆ

Luzula comosa E. Mey. Moist ground at Native Son Mine, alt. 5000 ft., Lower Transition Zone. (No. 1632.)

Juncus balticus Willd. Common in a small pasture at the Native Son Mine.

Juncus Mertensianus Bong. Abundant in marshy ground in a side cañon of Prairie Fork, alt. 7000 ft.; rare about the waterhole at Kellys Cabin, alt. 8350 ft. and not uncommon in the marshes in Coldwater Fork Lytle Creek, alt. 7000 ft. All stations are in the Upper Transition Zone. (Nos. 1390, 1502.)

Juncus Xiphioides E. Mey. Growing along the creek near the Native Son Mine, alt. 5000 ft. (No. 1684.)

LILIACEÆ

Allium Burlewi Davidson. Found only in exposed well packed granitic soil. Seen at Baldy Lookout, alt. 6000 ft., at the lower edge of the Transition Zone and as high as 9500 feet alt. in the Canadian Zone on Little Baldy. Always found in large colonies.

Differs from *A. tribracteatum* in its long pedicels and hence much looser heads, and in its more exerted stamens. The plants average larger and the flowers much lighter in color (petals white with definite pink midrib). In *A. Burlewii* the leaves are single, exceeding the stem only by a centimeter or so.

There is a peculiar form collected by Hall (No. 1497) at 6700 feet alt. in Swartout Valley which seems worthy of some nomenclatorial recognition. The perianth segments are long attenuate, 8–11 mm. long, on very slender pedicels 2 to 3 times as long. The broad, 6.5 mm. wide, green, leaf reaches 19 cm. in length which equals three times the length of the stem. (Nos. 1268, 2484, 1490.)

Allium Breweri Wats. In habitat this species is quite distinct from the last. That species demands well packed granitic soil while *A. Breweri* demands that it be very loose. A rock slide is its favorite situation. The plant is common in suitable situations from the Lower Transition Zone, at Baldy Lookout, up to the summit of Baldy in the Canadian Zone.

This station for *A. Breweri* is far south of the nearest known station. It is not surprising, therefore, that the plant is somewhat different from the typical northern plant. Our plants have much broader bracts than do specimens of the type collection (Brewer 1060 from Mt. Diablo). The leaves are terete and only 5 mm. at most in diameter and not flat and 10–13 mm. broad as in the typical form. Det. M. E. Jones. (Nos. 1263, 1446, 1543, 2031.)

Muilla serotina Greene. Occasional in dry ground in the lower part of the pine belt. Frequent at lower levels.

Bloomeria aurea Kell. Same range as the last.

Brodiaea capitata Benth. Ranging up into the lower part of the pine belt, frequent at lower levels.

Smilacina sessilifolia Nutt. Common in springy ground near the head of Coldwater Fork of Lytle Creek, alt. 7000 ft. Upper Transition Zone. (No. 1448.)

Yucca Whipplei Torr. This common valley species ranges well into the Transition Zone. One plant was noted at 8200 ft. alt. on the steep south slope of Ontario Peak.

Lilium Parryi Wats. Very common at 7000 ft. alt., Upper Transition Zone, in a small side cañon of Prairie Fork. (No. 1703.)

Lilium Humboldtii Roezl. & Leicht. A few plants along streams in the lower part of the Transition Zone.

Fritillaria atropurpurea Nutt. var. *pinatorum* (Davids.) Johnston, comb. nov. *F. pinetorum* Davidson. A single plant of this species was collected at the Old Hydraulic Mine, growing at 7750 ft. alt. in decomposed granite on a north-facing slope. Another single plant was found growing in a similar habitat at 7250 ft. alt. in Icehouse Cañon. Both stations are in the Upper Transition Zone. Dr. Hall (No. 1504) collected the plant in Swartout Valley at 6000 ft. alt.

This variety is distinguished from the species by its erect pedicels, slightly smaller flowers and stouter habit of growth.

Calochortus invenustus Greene. In decomposed granite in the Upper Transition Zone. Frequent. (Nos. 1397, 1606.)

IRIDACEÆ

Sisyrinchium orcophilum Bickn. Common in springy places in the Upper Transition Zone. Not seen lower than 6500 ft., nor higher than 8200 ft. alt. Certainly distinct from the valley form, being smaller, more slender and unbranched; the fruit is smaller and thinner walled; the flower is smaller and much darker in color. A good variety at least. Det. E. P. Bicknell. (No. 1409.)

ORCHIDACEÆ

Corallorhiza multiflora Nutt. Seen at three stations. At Kellys Cabin, the largest colony, the plants were growing in rich moist ground under the pines at 8250 ft. alt. A single plant was found in a rotting pine log on the saddle between Baldy and Pine Mt. Another individual was seen under the pines at 8750 ft. alt. on the west spur of Baldy. All these stations are in the uppermost part of the Transition Zone. (No. 1669.)

Limnorchis sparsiflora (Wats.) Rydb. Frequent in marshes in the lower two-thirds of the Transition Zone. Highest seen at 8000 ft. at the Old Gold Ridge Mine. Our lower station is the marsh below Camp Baldy, where it is very common at 4200 ft. alt. in the Upper Chaparral Belt. (No. 1433.)

Epipactis gigantea Dougl. With the last in the pine belt, but extending to much lower levels, reaching the foothills and valley. (No. 1529.)

SALICACEÆ

Salix cordata Muhl. var. *Watsoni* Bebb. Very common in springy ground in the Upper Transition Zone where it is usually found growing between 6500 and 8000 ft. alt. (Nos. 1286, 1408, 1665, 1955, 1980.)

Salix flavescens Nutt. Frequent in moist ground along creeks, above 7500 ft. alt. Always in the higher parts of the Transition Zone. A station quite different from any other seen, is in the Canadian Zone on Pine Mt. at an altitude of 8250 ft. On a small, dry, rocky bench, a stone's throw from the ridge crest, there is a colony of this willow. (Nos. 1287, 1394, 1683, 2033.)

Salix lasvigata Bebb. Found just within the pine belt on both sides of the mountains.

Salix Parishiana Rowlee? Specimens collected in a small meadow below the Native Son Mine were doubtfully referred to this species by Mr. C. Schneider. (No. 1685.)

Salix exigua Nutt. var. *virens* Rowlee. The willow mentioned here was found growing on the gravelly floor of a very narrow side cañon, alt. 7500 ft. in the Upper Transition Zone, near the head of San Antonio Cañon. The plants, which form a very large colony, are all less than a meter high, despite the fact that all branches are erect. The colony is further noteworthy in that the majority of the catkins examined showed the presence of both staminate and pistillate flowers.

Regarding the determination of this willow Mr. Schneider writes, "A very interesting form which might be *S. exigua virens* Rowlee *sensu stricto*, but it also much resembles *S. melanopsis Bolanderiana*." (Nos. 1401, 1665, 2095.)

Populus trichocarpa T. & G. Frequent in the lower cañons, but in the pine belt it is not common and apparently confined to the Upper Transition Zone. All the pine belt specimens seem to tend towards narrow leaves. The form *ingrata* Jeps., may be considered present, for occasional trees or parts of trees have distinctly lanceolate leaves. (No. 1447.)

Populus Fremontii Wats. Lower Transition Zone at 6500 ft. in North Fork Lytle Creek and at 5000 ft. alt. in Prairie Fork. A common valley species. (No. 1659.)

BETULACEÆ

Alnus rhombifolia Nutt. Common along streams in the Upper Sonoran and Lower Transition Zones. Ascending as high as 7000 ft. alt.

FAGACEÆ

Quercus Kelloggii Newb. Common around 6500 ft. alt. in Prairie Fork. Very abundant near the head of South Fork Lytle Creek and on San Sevaine Flat. (Nos. 1450, 1714.)

Quercus Wislizeni DC. Very common in the Upper Chaparral Belt and extending a short distance up into the Lower Transition Zone.

Quercus chrysolepis Liebm. Common in the lower cañons above 3000 ft. It ascends the mountains to a maximum altitude of 8500 ft. on the steep south

slope of Ontario Pk. Common throughout the Transition Zone. It becomes a low dense shrub, scarcely over a meter in height, near its upper limit.

Castanopsis sempervirens (Kell.) Dudley. Common from the upper part of the Transition Zone to Baldy Summit. The plant blooms in August during which time one is nearly sickened by its odor. (No. 1541.)

LORANTHACEÆ

Arceuthobium campylopodum Engelm. On *Pinus Lambertiana* at 7500 ft. alt. in Coldwater Fork Lytle Creek, and on *Pinus ponderosa* at 6500 ft. alt. in Prairie Fork. (Nos. 1688, 1720.)

Phoradendron libocedri Howell. On *Libocedrus decurrens* at 4700 ft. alt. in Prairie Fork and at 6500 ft. alt. in North Fork Lytle Creek. (No. 1718.)

Phoradendron villosum Nutt. On *Quercus chrysolepis* and occasionally *Q. Wislizeni*. (No. 1719.)

Phoradendron pauciflorum Torr. The common mistletoe in the pine belt, the only one attacking *Abies concolor*. So common is the plant below 7500 ft. alt., that hardly a fir can be found that is left unpreyed upon. (No. 1622.)

URTICACEÆ

Urtica holosericea Nutt. Abundant in the valleys, but only occasional in the Lower Transition Zone. We were surprised to find it abundant at 8000 ft. alt. in the Upper Transition Zone at the Old Gold Ridge Mine. (No. 1605.)

POLYGONACEÆ

Oxytheca caespitosoides Parry. Under the pines at Baldy Lookout, alt. 6000 ft., Lower Transition Zone. (No. 1259.)

Oxytheca Parishii Parry. Lower Transition Zone on both sides of the mountain; not common. (No. 1487.)

Eriogonum molestum Wats. var. *Davidsonii* (Greene) Jeps. Common in open sunny places in the Transition Zone. (Nos. 1583, 1406.)

Eriogonum nudum Dougl. Occasional on dry cañon sides throughout the Transition Zone. Flowers in late August. (Nos. 1588, 1699, 1702.)

Eriogonum elongatum Benth. Collected in the pine belt at 5250 ft. alt. in San Antonio Cañon and at 5000 ft. alt. in Prairie Fork. Common at lower altitudes. (No. 1716.)

Eriogonum fasciculatum Benth. var. *polifolium* (Benth.) T. & G. On sunny cañon sides throughout the Transition Zone. (No. 1569.)

Eriogonum Wrightii Torr. var. *subscaposum* Wats. Frequent on gravelly cañon floors and on exposed ridges in the Upper Transition and lower parts of the Canadian Zone. Blooms during the last of August. (Nos. 1544, 1581.)

Eriogonum saratile Wats. A common plant in the Upper Transition and Canadian Zones. A form of this species with a dark wine-colored calyx occurs on Baldy and Telegraph Pk. Summits. The only difference is in the color, and that was found to grade into the pale greenish yellow of the common form. (Nos. 1382, 1463, 1473, 1546, 1572.)

Eriogonum microthecum Nutt. We know it from only two stations. Along the crest of the ridge a little east of Cucamonga Pk. Summit at about 8700 ft. alt. and on the crest of the west spur of Baldy at 9000 ft. alt. Both stations are but small colonies situated in very rocky ground along a ridge in the Canadian Zone. Det. W. L. Jepson. (Nos. 1530, 1726.)

Eriogonum umbellatum Torr. Frequent in dry ground under the pines in the Lower Transition Zone. Never found in exposed places.

Abrams (Fl. Los Ang. 109. 1917) gives *Eriogonum stellatum* as "common in the coniferous forests." We think he must have reference to *E. umbellatum* since a careful observation has failed to detect any of our plants with the branched or bracted umbel rays which characterizes *E. stellatum*. (Nos. 1383, 1474.)

Erigeron umbellatum Torr. var. *minus* Johnston. A much reduced, ecological form which is common at the type station on Baldy Summit. The plant also occurs on the other peaks where it is confined apparently to the higher parts of the Transition Zone and to the Canadian. (Nos. 1584, 1692.)

PORTULACACEÆ

Calyptridium monandrum Nutt. Not uncommon in dry ground along the lower edges of the pine belt.

Calyptridium Parryi Gray. Frequent in the Canadian Zone on bare stretches of decomposed granite.

Calyptridium umbellatum (Nutt.) Greene. Common in open ground under the pines in the Upper Transition Zone and on bare ridges in the Canadian Zone. Ranging between 7500 and 9700 ft. alt. (Nos. 1273, 1397.)

Lewisia rediviva Pursh. Common in rocky exposed places throughout the Transition Zone. (Nos. 1280, 1412, 1470, 1493.)

Montia exigua (T. & G.) Jeps. var. *viridis* (Davidson) Jeps. Locally abundant on a sunny talus slope in the Upper Transition Zone, at 7000 ft. alt. in Icehouse Cañon. Collected "near Old Baldy" at 5750 ft. alt. by Dr. Hall (no. 1245). The type was collected in Rock Creek just west of our limits. (No. 2037.)

CARYOPHYLLACEÆ

Arenaria Douglasii Fenzl. Abundant in the spring under the pines along the lower edge of the Transition Zone. (No. 1356.)

Arenaria Nuttallii Pax. var. *gracilis* Rob. Collected on "Mt. San Antonio" by Prof. McClatchie acc. Jeps. Fl. Cal.

Arenaria macradenia Wats. Collected by Dr. Hall at 6500 ft. alt. in Swartout Cañon. (No. 1276.)

Silene Parishii Wats. Not common but generally distributed over the mountains. Confined to the upper parts of the Transition and Canadian Zones. Not seen below 7000 ft. alt. Usually found in rocky places but occasional in decomposed granite. (Nos. 1531, 1553, 1563, 1670.)

Silene Lemmonii Wats. Lower Transition Zone, alt. 4500–6500 ft. in Cascade Cañon. Shaded cañon side. (No. 1276.)

Silene verecunda Wats. *platyota* Wats. Jeps. Frequent in the Transition Zone. In the higher part of this zone it is very common in moist shaded ground under the pines. Here the plants are lower and much more slender than they are at lower levels and the calyx usually has a distinct purplish color which is absent in the Lower Transition form. (Nos. 1386, 1481, 1528, 1671.)

RANUNCULACEÆ

Aquilegia truncata F. & M. Common in springy places. Transition Zone and lower. (No. 1532.)

Delphinium hesperium Gray, var. *recurvatum* (Greene) Jeps. "San Antonio Mts., 5750 ft. alt. *Hall*" and "Lytle Creek Cañon, 5500 ft. alt. *Hall*" acc. Davidson, (Muhl. 4: 34, 1908).

Here, very likely, belongs the common larkspur noted in Prairie Fork of which we have seen only fruiting specimens.

Thalictrum polycarpum Wats. Common in moist ground bordering streams in the upper parts of Prairie Fork San Gabriel River and North Fork Lytle Creek, Upper Transition Zone, alt. 7000–8000 ft. Also at 5000 ft. in Prairie Fork. (Nos. 1677, 2093.)

Clematis ligusticifolia Nutt. Ranges from the lower cañons up to an altitude of 7000 ft. in the pine belt.

LAURACEÆ

Umbellularia californica Nutt. This Upper Sonoran tree ranges a short way up into the pine belt.

PAPAVERACEÆ

Argemone platyceras Linkk. & Otto, var. *hispida* Gray Prain. With wide distribution in the mountain but not especially common. In the Upper Transition Zone at 9000 ft. on the Devils Backbone and at 8000 ft. alt. at the Old Gold Ridge Mine. In the Lower Transition it is not uncommon in the sandy ground in Prairie Fork and North Fork Lytle Creek.

CRUCIFERÆ

Draba corrugata Wats. *D. vestita* Davidson. A very common and characteristic plant of the Canadian Zone. Usually growing under the pines, but on Baldy Summit it is common among loose rocks.

A plant collected by Burlew on Baldy Summit was made the type of *D. vestita*, a species described by its author as differing from *D. corrugata* in being more hirsute and more compact in habit, and in having shorter petals and less corrugated fruit. Dr. Davidson mentions certain collections from the San Jacinto Mts. that in his mind represent typical *corrugata*. From our studies of herbarium material it appears that *D. corrugata* is represented in the San Jacinto Mts. by a very distinct geographical variety that is characterized by its long petals, slightly smaller and more contorted fruit and by its slender, naked, unbranched stems bearing a simple, open few flowered raceme.

The plants from the San Antonio Mts. and those from the San Bernardino Mts. agree in having very short inconspicuous petals, rather large, little contorted fruit and stout, leafy, much branched stems that form dense, many flowered panicles. This form is apparently the typical plant for the type was collected by Lemmon on Grayback in the San Bernardino Mts. It thus appears that *restita* was described through a misconception as to what constituted the true *caerugata* and that the well marked variation on Mt. San Jacinto through which this misconception arose, is still without a name. (Nos. 1279, 1416, 1609.)

Sisymbrium canescens Nutt. Dry sandy ground in the lower part of the pine belt Common in the chaparral belt

Dentaria californica Nutt. Rare in cool, moist places in the lower parts of the pine belt; frequent in the Upper Chaparral Belt.

Arabis arcuata Gray. Frequent in dry rocky ground throughout the Lower Transition Zone. It descends the cañons on the south side and reaches a minimum altitude of 1000 ft. in the gravelly wash of San Antonio Cañon.

The pine belt form has its pods uniformly shorter than the Upper Sonoran plant. The valley and chaparral belt plant has pods 7–9 cm. long; the pine belt form has its pods only 3–5 cm. in length. (Nos. 1359, 1589, 1951, 1952, 1956, 1973.)

Arabis glabra L. Bernh. Occasional in the lower parts of the pine belt; common at lower levels.

Arabis repanda Wats. Frequent in dry open ground under the pines in the Upper Transition Zone. (Nos. 1464, 1663.)

Arabis platysperma Gray. Frequent under the pines in the Upper Transition and Canadian Zones. Exceedingly abundant in the vicinity of Kellys Cabin. A single plant was found on Baldy Summit. (Nos. 1465, 1560.)

Erysimum asperum DC. Common in dry open ground under the pines in the Lower Transition Zone.

Streptanthus campestris Wats. var. *bernardinus* (Greene) Johnston, comb. nov. *Agianthus bernardinus* Greene. Shaded ground under the pines in South Fork Lytle Creek, alt. 6000 ft.

This variety is a lower and more slender plant than the species with smaller, yellow flowers which have recurved sepals. Though quite distinct in their extremes, the species and the variety are well connected by intermediate forms. (No. 1477.)

Caulanthus amplexicaulis Wats. Common in dry situations throughout the Transition Zone. (Nos. 1267, 1467.)

CRASSULACEÆ

Dudleya pumila Rose. *D. minor* Rose. Not uncommon in crevices of granite. Usually found on sunny ledges but occasionally also in shaded cañon walls where it takes on a different form.

In exposed situations this plant has compact rosettes of very glaucous nearly ovate leaves. The stem averages less than 5 cm. in height bearing densely flowered (30 per. plant) compounded cymes of reddish colored flowers. When the plant grows in a cool cañon the rosette is very much looser and the

leaves sparingly glaucous and oblong in shape. The stems are very slender and average about 10 cm. in height. The cyme is not compounded much and consists of usually less than 15 flowers, these latter being very pale yellow in color.

D. minor appears to be only a form of *pumila* that has broader calyx lobes. This plant has at various times been placed under *Dudleya nevadensis* but that is a very different plant and has a more northern range. (Nos. 1289, 1643, 1646.)

Sedum anomalum (Britton) B. & R. On the west end of Ontario Peak, in Cascade Cañon, this is very abundant on a talus-covered north-facing slope. Lower Transition Zone, 4500–6500 ft. alt. Det. J. N. Rose. (Nos. 1288, 1814, 2053.)

SAXIFRAGACEÆ

Boykinia rotundifolia Parry. Frequent in moist places in the Upper Sonoran and Lower Transition Zones, reaching its maximum altitude of 6500 ft. in Icehouse Cañon.

Heuchera Abramsii Rydb. Common at the type station on Baldy Summit. We found the plant also on the west spur of Baldy and on Pine Mountain. On these ridges it descends to the lower edges of the Canadian Zone, where it was found to grow with *H. elegans*. We looked for signs of intergradation but none could be detected even when the two species grew near each other. (Nos. 1417, 1690, 1728, 2096.)

Heuchera elegans Abrams. Frequent from the Upper Chaparral Belt to the lower part of the Canadian Zone. Always growing in very rocky situations. At 5000 ft. alt. is about the lowest we have seen the plant, while 9000 ft., on Telegraph Pk., is about the highest. The plant, in the San Antonio Mountains at least, is by no means an Upper Chaparral Belt species as it has been thought to be. (Nos. 1395, 1456, 1559, 1561, 1733.)

Ribes montigenum McClatchie. Baldy Summit is the type station of this widely distributed subalpine shrub. It is common there, growing in the shelter of the rocks that are scattered near the summit. On the west spur of Baldy it descends to the 9000 foot contour, the lowest altitude at which it was seen. To be expected on Pine Mountain, but we failed to find it there. (No. 1415.)

Ribes cereum Dougl. Common in the higher parts of the Transition Zone and through the Canadian Zone, reaching Baldy Summit. (Nos. 1272, 1419.)

Ribes nevadense Kell. Common in damp ground along the streams in the Transition Zone. In the Upper Transition Zone it is often found growing in the shade of the pines at some distance from water. This species is one of the characteristic plants of the Transition Zone. (No. 1403.)

Grossularia Roezli (Regel) Cov. & Britt. Frequent in various situations in the Upper Transition and in the lower part of the Canadian Zone. (No. 1271.)

Grossularia amara (McClatchie) Cov. & Britt. Ranging a short distance up into the pine belt. Frequent in shaded places in the Upper Chaparral Belt.

(To be continued.)

BOOKS AND CURRENT LITERATURE

Preparation of Seed Potatoes. One of the best station bulletins that has appeared recently is the one from Maryland written by C. O. Appleman.[1] In the practical application of a fundamental physiological principle it is far ahead of the usual run of station bulletins. It is scientific, exact, and yet so simply planned and presented that a practical individual interested in better potato yields can understand it. We need more station bulletins of this type.

Appleman's bulletin on the Physiological Basis for the Preparation of Potatoes for Seed has in view as its chief object the preparation of seed for the practical growing of potatoes. It deals with such questions as the relative values of the eyes on different parts of the tubers, the size and form of the seed pieces, and the method of cutting the tuber. These questions are discussed with special reference to the influence of factors inherent in the tuber. Some of the more important conclusions may be summarized as follows:

Terminal eyes suppress or retard the growth of other eyes on the tuber. The degree of this growth inhibition is influenced by the variety, size of the tuber, vigor of the terminal sprouts and external condition.

It is these internal growth inhibitory influences which should receive most consideration in formulating a practical procedure for cutting the tuber for seed.

Eyes on the stem half of the tuber are capable of producing vigorous sprouts, when their connection with the terminal eyes is severed and they are just as valuable for seed, all other conditions equal, as the eyes on the terminal or seed half of the tuber.

The vigor of the sprouts depends upon the size of the seed piece. Within certain limits, the yield of tubers increases directly with the weight of the seed piece. The size of the seed piece can easily therefore become the limiting factor in the crop yield. The seed piece must not weight less than 1.5 oz.

[1] Appleman, C. O. Physiological Basis for the Preparation of Potatoes for Seed. Md. Agric. Exper. Sta. Bull. 212. 1918.

In cutting the tuber for seed, the size of the piece should be the criterion to have in mind rather than the number of eyes to the piece. The piece should be compact and as nearly uniform in size as possible. One eye, or even half of an eye to a piece, will suffice if the piece is of suitable size.

The idea that the terminal eyes are more vigorous and for that reason each piece should bear one or more of these eyes, may be safely eliminated in practice. In order to make use of the middle or basal eyes for seed, they must be separated from the terminal eyes.

Buds near a cut surface will produce sprouts more quickly than those in the middle of the piece. Cutting the tubers from side to side as much as possible will bring the most eyes near a cut surface.

This investigation should settle for once and all the conflicting opinions, ideas and experimentations regarding the preparation of potatoes for seed.—R. P. Hibbard.

Our National Forests.—We have had many books describing the beauties and scenic grandeur of the National Forests and National Parks, and it is satisfying to find that the recent volume by Boerker[1] is not a mere addition to this number. It is, on the other hand, an account of the history and administration of the Forest Service and a complete picture of its work. The fact that the author is no longer connected with the Service enables him to speak appreciatively of its activities, at the same time that his seven years of work in the western National Forests have given him a first-hand familiarity with his subject. The history of the early movements for national control of our forests is given, and also that of the rapid growth of the "forest reserves," as they were then called. The administration of the forests is described, with reference to the duties of the district supervisor, the supervisor of each forest, and the men from whom technical and legal advice is secured. All aspects of the field work on National Forests are described and illustrated, including the gathering of the seed crop, reforestation, fire protection, the building of roads, trails, and telephone lines, and the supervision of grazing and lumbering operations. The importance of the forests as sources of water and as public recreation grounds is brought out with considerable emphasis. Boerker's book displays in every chapter the fine *esprit de corps* that has made the

[1] Boerker, Richard H. D. Our National Forests. Pp. 69 + 238; figs. 80. New York, The Macmillan Company, 1918.

administration of the National Forests so efficient, and the enthusiastic devotion of its men, which has done so much to win public respect for our national forest policy. It is fine to have such a well executed and amply illustrated book for the dissemination of sound information about our National Forests.—FORREST SHREVE.

A RECENT STUDY OF CLUB ROOT.—Kunkel's recent work[1] on *Plasmodiophora* disproves the idea so widely prevalent that infection of cabbage plants must occur through the root hairs. In his experiments paper cylinders were fastened around the roots of healthy plants after the latter had been washed free from earth, at places free from branches. The cylinders were then filled with earth containing the spores of *Plasmodiophora* and sealed with paraffin the roots were covered with moist earth, and the plants were examined at the end of two weeks. Infection always occurred within the cylinders regardless of the location on the root, and in no case did it arise outside. The experiment appears to demonstrate clearly that the parasite can enter tissue far back of the root-hair region. Supplementary study of prepared slides revealed the parasite below the root hairs in the root-tip in some of his material. Stems were also found to be capable of infection. Two thousand plants varying in age from one to twelve months were inoculated in the stem, and infection followed in every one. Cells become infected by host cell division and by penetration of the parasite through the wall of an infected cell into normal ones. Nuclei respond to the stimulus of the parasite by a greater proportional enlargement than the cytoplasm shows, and this response is evident in cells at a considerable distance from the infected spot. The club root is first noticeable as a slight swelling in about eleven days, but two weeks are required before the cambium is penetrated. The mass of parasitic protoplasm bears a remarkably constant ratio to that of the host. Wilting of the host is due to hypoplasia of xylem, and to the splitting of the woody cylinder caused by the infection and growth of the medullary rays. J. G. BROWN.

[1] Kunkel, L. O. Tissue Invasion by *Plasmodiophora Brassicae*. Jour. Agric Res. **14**: 543–572; pl. 20. 1918.

NOTES AND COMMENT

The cultivation of the Washington navel orange has gradually been extended in southern California from the humid coastal regions to some of the arid interior valleys, where the yield is greatly reduced by the premature fall of young fruits. J. E. Coit and R. W. Hodgson have recently investigated the cause of the "June drop" of young oranges (Univ. Cal. Pubns. in Agrl. Sci., vol. 3, no. 11), establishing the fact that the arid conditions of such localities as the southern San Joaquin Valley are directly responsible for the drop. Evidence is given to show that high rates of transpiration cause such a reduction in the water content of the tissues that the formation of a definite abscission layer takes place in the stems of the young fruits. Amelioration of the local atmospheric conditions by the growing of irrigated crops near by has been found to reduce the loss in the oranges. By a comparison of local evaporation rates with those of the great continental areas it is shown that an irrigated crop growing in the proximity of an orange grove serves to reduce the evaporation from a rate like that of Tucson, Arizona, to one near that of Miami, Florida.

The climatic maps of the United States, or of individual states, show such widely separated and gracefully sweeping isoclimatic lines that we are prone to overlook the very considerable differences of climate that may exist within very small areas. These differences may well be of great agricultural importance even in less diversified states than California.

An interesting paper has been contributed to the January-March issue of the American Fern Journal by Mr. Ellsworth P. Killip, describing the fern flora of Panama. The lowland jungles of the Canal Zone were visited and also the summit of the Sierra Chiriqui, which forms the continental divide north of the isthmus. Both localities were found to have a rich and varied representation of ferns.

EARLY SPRING AT THE GRAND CAÑON NEAR EL TOVAR

ALICE EASTWOOD

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The middle of April, 1917, found spring just commencing at the rim of the Grand Cañon but far advanced at the river almost 5000 feet below. A few small flowers had begun to creep out and unfold their hardy blossoms. Snow may come again after this date as it did in fact in 1917. The first flower to appear is *Thlaspi fendleri*, like a small white candy-tuft dotting the ground under the trees. *Pedicularis centranthera* is pushing up its rosy hoods amid a rosette of purple-red leaves, with crinkled edges. Two low umbellifers indicate their presence by clusters of finely dissected leaves. The one with smooth glaucous leaves is probably *Phellopterus purpurens* and the other with leaves frosted with fine white lines is *Cogswellia macdougali*. On low leafy green cushions repose large white daisies with pink-tinged rays not yet open. Undoubtedly this is the widely distributed *Townsendia exscapa*. Other rossettes of leaves can be seen. One belongs to *Senecio multilobatus* with the leaves cut into numerous lobes and edged with cottony down; another is that of *Frasera albomarginata*, with narrow grass-like leaves each neatly edged with a white border. Other strangers appear whose identity cannot be guessed.

The pines and juniper form a shelter for these small vernal plants. The tall yellow pine, a variety of *Pinus ponderosa* has three long needles in each sheath; the spreading piñon (*Pinus edulis*) has two shorter leaves in each sheath. As the elevation increases towards Grand View the yellow pine predominates, while at the lower elevation of Hermits Rest it is entirely replaced by the piñon. El Tovar is about the dividing line between the Transition Zone, characterized by the

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yellow pine, and the Upper Sonoran Zone where the piñon prevails. The juniper characteristic of this region, and growing commonly with the piñon is the Utah juniper (*J. utahensis*). The bark is shreddy and the berries bluish. Just below the rim a few trees of douglas spruce (*Pseudotsuga mucronata*) can be seen with dark green, single, needle-shaped leaves surrounding the branchlets and brown persistent pendent cones. The white fir (*Abies concolor*) is at the rim where the Grand View trail begins and can be distinguished by the upright cones, which fall to pieces when

Fig. 1. In the dense forest of juniper and piñon south of El Tovar. (Photograph by Forrest Shreve

the seeds are ripe, leaving the axis erect on the branch, and by the pale green, two ranked linear leaves, like flattened needles. The piñons and the junipers extend far down the cañon walls but the other conifers are only near the rim. Where the piñon stops the Lower Sonoran Zone begins with characteristic vegetation.

Scrub oaks and attractive shrubs are scattered under the coniferous forest. The oaks are especially numerous under the yellow pines and belong to the common species *Quercus gambelii* characteristic of the yellow pine areas throughout

this region. In April they were without flowers or leaves. The rose family has some beautiful representatives easily distinguished by the persistent leaves. The cliff rose (*Cowania stansburiana*) is the most abundant. It has minute fan-shaped divided leaves with the edges turned under and a viscid lower surface. This shrub has flowers like those of the strawberry, close to the stem and followed by small bunches of curling plumes that surround every branch with a halo. The mountain mahogany has similar feathers to carry off the seeds, but only one to each flower, and the flowers are not especially noticeable, being small and brownish green. One species, *Cercocarpus ledifolius*, has narrow smooth shiny green leaves with the edges folded under, while the other, *Cercocarpus parvifolius*, or a variety of that species has small toothed pubescent leaves. The most attractive of all these rosaceous shrubs is *Fallugia paradoxa*, the Apache plume. The leaves resemble those of the cliff rose but are downy instead of viscid on the lower surface. The flowers are like small white roses daintily tipping slender white stems and are followed in fruit by gray, pink-tinged pompons that have suggested the appropriate common name.

Another rosaceous shrub quite common along the rim is *Chamaebatiaria millefolia*. The leaves are fern-like with fine delicate divisions and the flowers are in a close panicle surmounting the stems. The dry seed-pods persist all winter on the shrubby stems. Several varieties of service berry (*Amelanchier*) grow in the cañon and along the rim. Down in the cañon the bushes are in full bloom while at the rim the buds are not yet beginning to open. Entire bushes are clothed with a mantle of white, followed later by blue-black berries somewhat resembling the fruit of the hawthorn. A striking shrubby barberry is common along the rim and also lower down. Clumps of it several feet high can be seen here and there from the train after leaving El Tovar. The leaves are compound, with three or five leaflets, armed along the edges with sharp spines. In June these bushes are laden with racemes of yellow flowers and have great beauty. The large-leaved large-fruited yucca (*Y. baccata*) is found with the junipers and barberries.

Two species of indian lemonade have begun to flower on the leafless stems. Numerous yellow-green flowers cover these bushes, later to be clothed with leaves and laden with the acid-coated red berries. They belong near the sumachs and are generally included under *Rhus trilobata*. Two distinct forms of this shrub are found in the cañon, one with simple scalloped leaves, found only at lower elevations, has been named *Schmaltzia* or *Rhus affinis* and the other is probably *Schmaltzia* or *Rhus hirtella*.

Fig. 2. The edge of the open yellow pine forest between Grand Cañon and Williams. Photograph by Forrest Shreve.

Everywhere is the sage-brush, *Artemisia tridentata*, with dark stems and gray-green foliage, giving rise to the common name black sage. Several different species of *Artemisia* grow along the rim and down in the cañon but are not noticeable in the spring, belonging distinctly to the fall flora. The same may be said of the rabbit-brush, *Chrysothamnus*, which is related to the golden-rod and has large bunches of yellow or straw-colored flowers terminating the stems and branches. However, even in the winter, the rabbit brush gives a greenish yellow tone to the landscape noticeable for miles between Williams and El

Tovar. In saline or alkaline flats the salty sage or *Atriplex* prevails and there is such an area between Williams and El Tovar where nothing else seems to grow. There are several species of *Atriplex* but the most common is *Atriplex canescens*, which has circular fruits with several wings surrounding the seed. These often persist so that even in winter the species can be identified.

The odd reed-like shrubs that resemble clumps of *Equisetum* are common from the top to the bottom of the cañon. The common name is Mormon or Brigham tea and the tea has a great reputation as a blood purifier. These peculiar shrubs are related to the pines and other conifers in having naked seeds. Botanically they are known as *Ephedra*. The male plants are covered at the joints with bunches of yellow stamens, while the female plants have green seeds, two seeds to each cluster. At the lower end of the cañon a different species is found. The deep green one along the rim is *Ephedra viridis* and the pale green one is probably *Ephedra antisyphilitica* found only at lower elevations.

May and June are the months in which flowers are most common along the rim of the cañon. Then the indian paint brush (*Castilleja*), the pentstemons, the blue flax, woodland star *Lithophragma*), alum root (*Heuchera*), potentillas, mariposa tulips, evening primroses, gilias, fritillarias, arenarias and many more make the whole place a lovely garden of flowers. In July and August summer rains occur and bring about a second flowering of many of these shrubs and herbs, so that when these are added to the regular fall flora, September will produce a greater number of species in bloom than May or June, but the flowers are not so gay in color nor so abundant.

A THERMO-ELECTRICAL METHOD FOR THE DETERMINATION OF LEAF TEMPERATURE

EDITH BELLAMY SHREVE

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During the past year I have obtained successful results in determining the surface temperature of plant leaves by means of a thermo-electrical method. The method differs from previously used ones in the fact that the leaves are not wounded and in the consequent avoidance of the temperature complications which have been shown to result from the wounding of plant tissues.

The essential part of the apparatus is a thermo-couple,[1] one junction of which is so fastened to a light spring clip that it is held in position on the surface of the leaf. The other junction is placed beside a mercury thermometer in a small thermos bottle. A portable galvanometer and a damping key complete the main parts of the apparatus.

The details of the instruments are shown in figure 1. *A*, *B*, and *C* are diagrams representing the top, side and end views of the spring clip. The clip is made of brass spring wire, the ends of which pass through small pieces of cork at the points marked *a* and *b*. The size of the clip and strength of the spring vary somewhat with the size and thickness of the leaf to be measured. I found No. 00 wire to be most universally useful. A single turn of wire is made around one pair of the cork-tipped ends. From *c* to *e* the wire is No. 40 copper and from *e* to *d* No. 40 "Ideal" wire. The joint at *e* is made by the cold soldering process and must be very little thicker than the wires. The wire is insulated on the top and sides but not on the bottom, where it touches the

[1] In response to my request the design of construction of the thermo-couple was made by Mr. M. S. Van Duesen, of the U. S. Bureau of Standards, and I am also indebted to him for helpful suggestions.

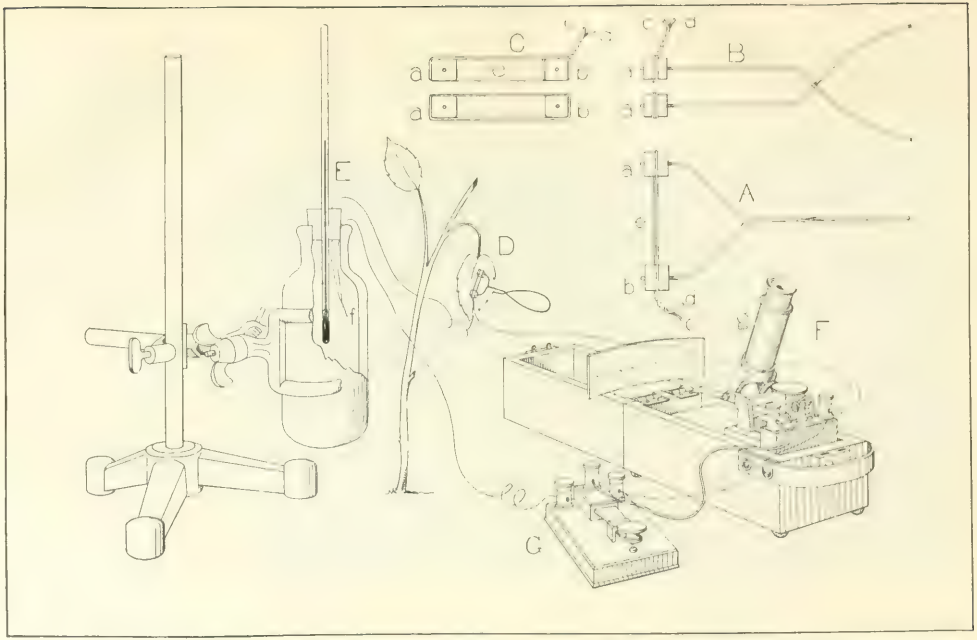

Fig. 1. Diagram of apparatus for determining leaf temperature. *A*, *B*, *C*, Top, side and end views of clip for holding thermo-junction on the leaf. *D*, Clip containing thermo-junction in position on a leaf. *E*, Second thermo-junction in the air of a thermos bottle. *F*, Portable telescopic galvanometer. *G*, Damping switch.

leaf. Around the other pair of cork tips are wound several turns of silk thread. The leaf passes between the two sets of corks so that the junction c touches its surface. The silk threads then touch the other surface of the leaf and act as a support for holding the clip in place. The clip is represented in position on a leaf at D. E shows the other thermo-couple hanging free in the air of a thermos bottle. At F is represented a portable telescope galvanometer of high sensitivity, one volt passing through a resistance of 40 megohms or more, causing a deflection of 1 scale division. The instrument which I used has withstood a year of very rough field service.[2] At b is shown a two-way switch with connections made so that the galvanometer is always closed excepting for the second when the thermo-couple circuit is opened for a reading. This key thus dampens the galvanometer swings so that the readings may be taken without loss of time. All wires are insulated excepting at the thermo-junctions.

To find the temperature of a leaf it is necessary to know only the temperature of the junction in the thermos bottle and the throw of the galvanometer, provided the galvanometer has been previously calibrated. The calibration is made by placing the clip A in another thermos-bottle which is fitted with a stopper and mercury thermometer. The temperatures of the air in the two bottles are then made to differ by any convenient amount, for example 10 C. The key is then pressed and the throw of the galvanometer read, and the deflection for 1° calculated. The galvanometer is so sensitive that a difference of 0.1°C., between the two junctions can be detected; consequently there is no need to carry ice in the thermos bottle. It is necessary to place the junction f inside a thermos bottle because the lag of a mercury thermometer is too great to register the frequent and rapid changes of temperature that take place in the free air in the field. The air in the thermos bottle may, of course, be either above or below the temperature of the outside air. I found it convenient in field work to start the morning

[2] The instrument is supplied by the Leeds & Northrup Company, Philadelphia.

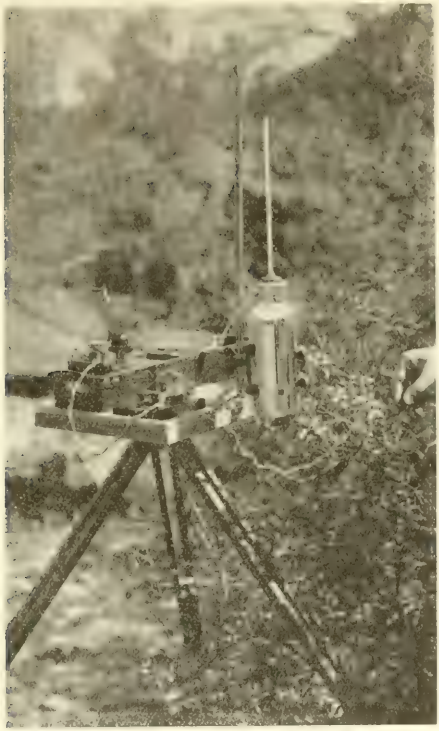

Fig. 2. Leaf temperature apparatus set up for field use.

readings by closing the bottle with the cooler night air within and to have the bottle stoppered all of that day and the following night. Since the temperature of a leaf is usually of interest only when it is compared with the temperature of the air, it is best to take readings of the air temperature immediately before and after the temperature of the leaf is read. This can

always be done by taking a galvanometer reading with the clip in the air instead of on a leaf.

Figure 2 shows the various units assembled on a board about 7 inches square. The board is screwed to a photographic tripod and the whole may be easily moved about from plant to plant and the height quickly adjusted to suit the position of the leaf under observation. In order to avoid undesirable thermal currents the entire apparatus must be either in the sun or in the shade. It is almost impossible to avoid shading parts of the instruments with the hands or body of the observer and consequently it is more convenient to provide a shade. A doll's parasol fastened by a clamp to the rod holding the thermos bottle was found useful. The leaf to be measured can remain in the sun until the clip is placed on it. It requires only a fraction of a second for a reading to be made; so no measurable change in the temperature of the leaf can take place before the reading is made.

THE FLORA OF THE PINE BELT OF THE SAN ANTONIO MOUNTAINS OF SOUTHERN CALIFORNIA

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Continued

PLATANACEÆ

Platanus racemosa Nutt. Ranging a short distance up into the pine belt, but characteristic of lower altitudes.

ROSACEÆ

Sericotheca concolor Rydb. Common in dry exposed places in the Canadian Zone and not uncommon on dry, open, sandy cañon floors of the Upper Transition Zone. In both Icehouse Cañon and Middle Fork Lytle Creek it was found at as low as 6500 ft. alt. (Nos. 1270, 1566, 1570, 1582, 1696.)

Amelanchier alnifolia Nutt. Icehouse Cañon at 7250 ft. alt. and at 7000 ft. alt. in both Coldwater Fork Lytle Creek and Prairie Fork. The first station is on a dry rocky place on the cañon floor while the other stations are both in springy ground.

Our plants have the glabrous hypanthia and sepals of the segregate, *A. recurvata* Abrams. *A. venulosa* Greene, another segregate of *A. alnifolia*, is reported from Swartout Valley by Abrams (Bull. N. Y. Bot. Gard. 6:382, 1910). (Nos. 1388, 1539, 1681, 1711.)

Heteromeles arbutifolia Roem. Enters the pine belt in Prairie Fork and in San Antonio Cañon.

Drymocallis viscida Parish. Common in moist ground in the Transition Zone. (Nos. 1410, 2062, 2068, 2072.)

Drymocallis lactea (Greene) Rydb. Locally very abundant in a marsh in a small side cañon of Prairie Fork. Upper Transition Zone, alt. 7000 ft. (No. 2066.)

Cercocarpus betulaefolius Nutt. Frequent in the lower parts of the pine belt.

Cercocarpus ledifolius Nutt. As a shrub at its lower limits and a tree in its upper ranges, this species extends throughout the Transition Zone and well into the Canadian. (No. 1485.)

Rubus leucodermis Dougl. Occasional in moist rocky ground in the Transition Zone. (No. 1462.)

Rubus parviflorus Nutt. "In moist shady places in the San Antonio and San Bernardino Mountains in the pine belt." Acc. Abrams, Fl. Los. Ang.

Prunus fasciculata Walp. Scarce on the south side of the mountains, but common on the north side. Especially abundant in Prairie Fork between 5000 and 7000 ft. alt. A few plants grow on the Devils Backbone at 9000 ft. alt. The species is confined to the Transition Zone. (Nos. 1384, 1402, 1712.)

Prunus ilicifolia Nutt. In San Antonio Cañon this enters a short distance up into the pine belt.

Prunus emarginata Walp. We know the plant from only two stations, both of which are in the Transition Zone, one in the lower part, the other in the upper. Coldwater Fork Lytle Creek, alt. 5750 ft. and near the head of San Antonio Cañon at 7600 ft. Dr. Hall collected the species also at 5700 ft. in Lytle Creek (No. 1471) as well as "north of San Antonio Peak at 8500 ft. alt." Our plant is a shrub which is seldom higher than $1\frac{1}{2}$ meters and is similar in pubescence to the var. *mollis* Brew. (Nos. 1666, 1680, 2079.)

Rosa Californica Cham. & Sch. Barely entering the pine belt.

Rosa gratissima Greene. Several large thickets of this rose were found in a moist meadow near the Native Son Mine in Prairie Fork.

Specimens were sent to Dr. Rydberg who determined them as *R. mohavensis* Parish. Mr. Parish, however, is very unwilling to see our plants referred to this species so we are following Abrams (Bull. N. Y. Bot. Gard. 6: 380, 1910) in referring this form, which he collected in Swartout Cañon, to *R. gratissima*. In Rydberg's key (Bull. Torr. Bot. Club 44: 65, 1917) our plant seems to fall into *R. mohavensis*. Our plants, as well as those collected by Hall (No. 1513) at 6200 ft. alt. in Swartout Valley, differ from the roses collected near the type station of *R. mohavensis* in being more or less distinctly bicolored, slightly puberulent, darker, and not at all shiny. (No. 1704.)

LEGUMINOSÆ

Lupinus Grayi Wats. We are placing under this species all our lupines which have a woody caudex. The species thus defined contains two well marked forms which after some study may prove to be distinct species. On the south side of the mountains the plants are low, seldom over 2 dm. high, and compact. The racemes are few flowered and the leaves are small, never over 2.5 cm. wide, and rather short petioled, 1–2.5 times as long as the leaves. On the north side of the mountain the stems are very much higher, 3–7 dm. high while the plant is very open. The racemes are many flowered, the leaves are all over 3 cm. wide and the petioles are 3–5 times the length of the leaves. The stems of this second form very much resemble the branches of *L. Hallii*, indeed if the evidence of caudex were destroyed on one of the taller specimens of this form we very much doubt whether they could be distinguished from that species.

Common in dry open ground under the pines in the Lower Transition Zone. The color range of this species is considerable. In most any colony, a color series is usually obtainable, ranging from pure white through pink to dark blue. (Nos. 1479, 1491, 1492, 2064, 2078.)

Lupinus formosus Greene. Common on dry slopes with the last and descending to the valleys.

We feel certain that there are too many forms referred to this species

that a critical study will result in recognizing a large number of good varieties and perhaps even several good segregate species. In the San Antonio Mts. we have observed several forms of this plant. In dry open ground in the lower parts of the pine belt the plants are very open, the leaflets linear, folded and covered with rather dense, long pubescence. The common form of the species, which has larger, broader and unfolded leaves has two well marked forms of inflorescence. In very dry sunny ground the racemes are elongated and few flowered, and the flowers have long pedicels, 5–10 mm. long. Contrasted with this form is the plant which has dense racemes of short pediceled, 2–4 mm. long, flowers. A plant is common in Prairie Fork which we place under this species with great hesitancy. The habit of growth is very different from the other forms referred here, it being erect and branching above. The racemes are short and of seemingly smaller, usually white, flowers. (Nos. 1269, 1469, 1488, 2086.)

Lupinus ceptisoides Agardh. Abundant along the streams in the upper parts of Prairie Fork San Gabriel River and North Fork Lytle Creek, 6000–7500 ft. alt., Upper Transition Zone. In the Lower Transition Zone it was only noted at 5400 ft. alt. in San Antonio Cañon. (No. 2074.)

Lupinus clatus Johnston. The most conpicuous herbaceous plant in the area centering around Kellys Cabin. The plant flowers continuously from the middle of June to late autumn, when it is killed to the ground by the frost. Its altitudinal range is between 6500 and 8700 ft. alt. It is found on the low Canadian Zone slopes above Kellys Cabin but it is apparently more at home on the shaded slopes in the Upper Transition Zone.

At the time the plant was described we knew it only from the type region but we have since found it on the south spur of Cucamonga Peak where it was common on what is sometimes known as Manzanita Flats, alt. 6500 ft. The flowers range from flesh color to light blue. The plants collected on the south slope of Cucamonga Peak are slightly lower than those at the type station, and the leaflets are all under 6 mm. in length. (Nos. 1626, 1627, 2063.)

Lotus nevadensis (Wats.) Greene. (*L. Davidsonii* Greene.) Fairly common in dry open ground under the pines in the Lower Transition Zone. At Kellys Cabin, located on the upper edge of the Transition Zone, alt. 8200 ft., this plant is common on the small flats on which the cabin is located. This station is unusual since the ordinary altitudinal range is between 5500 and 7000 ft. alt.

Dr. Abrams (Fl. Los Ang.) says of *L. Davidsonii*, "very close to *L. argophyllus* and may be only a form of it." We do not agree with this statement for we believe that that species is identical with *L. nevadensis* (Wats.) Greene. The "argophyllus group" can be separated from the "nevadensis group" by its shiny-silk pubescence and its mucronate leaflets. These differences are much better differentiating characters than the relative lengths of the peduncles, which Abrams (*l.c.* 200, 1917) uses to separate them. We have found that the peduncles are very variable in length, even in a single collection. The lateness of the season in which the specimen was collected seems to determine, partly at least, the length of its peduncles. (Nos. 1423, 1552, 1458.)

Lotus argophyllus (Gray) Greene. (*Hosackia argophylla* Gray var. *decora* Johnston.) Most common in rocky ground in the lower part of the pine belt, frequent in the Upper Chaparral Belt and not uncommon in gravelly washes near the cañon mouths. (Nos. 1278, 1737.)

Lotus Heermanni (D. & H.) Greene. Occasional in moist sand along creeks in the Lower Transition Zone, much more common at lower levels. (No. 1657.)

Lotus oblongifolius (Benth.) Greene. Occasional in moist ground in the Lower Transition Zone.

Lotus crassifolius (Benth.) Greene. Occasional in dry open ground, Upper Chaparral Belt and Lower Transition Zone. (Nos. 1495, 1751.)

Lotus strigosus (Nutt.) Greene. Under the pines at 5700 ft. alt. in San Antonio Cañon.

Lotus americanus (Nutt.) Bisch. Lower edge of the pine belt at 5000 ft. alt. in Prairie Fork.

Trifolium monanthum Gray var. *Grandianum* (Heller) Parish. Common in springy places in the Transition Zone above 6500 ft. alt. (Nos. 1392, 1550.)

Astragalus Parishii Gray. This species was collected by Hall (Nos. 1248, 1531) in Swartout Valley at 6700 and 6862 ft. alt.

Astragalus lentiginosus Dougl. var. *Fremontii* Wats. Frequent under the pines on the broad, dry, sandy floor of Prairie Fork, ascending the cañon to 6500 ft. alt. This and the next were determined by Prof. M. E. Jones. (No. 1655.)

Astragalus bicristatus Gray. Growing with the last in Prairie Fork but also on the west end of Ontario Peak in Cascade Cañon, where it is common under the pines, 6000–7000 ft. alt. Both stations are in the Lower Transition Zone. (Nos. 1656, 2039, 2056.)

EUPHORBIACEÆ

Tithymalus Palmeri (Engelm. Abrams. Collected by Dr. Hall (No. 1532) in Swartout Cañon at 6800 ft. alt.

ACERACEÆ

Acer macrophyllum Pursh. Common along streams in the Upper Chaparral Belt and Lower Transition Zone. Reaching 7300 ft. alt. (No. 1568.)

RHAMNACEÆ

Rhamnus californica Esch. Frequent in dry sunny ground throughout the Transition Zone, reaching an altitude of 8300 ft. (No. 1568.)

Rhamnus californica Esch. var. *tomentella* Brew. & Wats. Seen only in Prairie Fork San Gabriel River and in North Fork Lytle Creek, where it grows with the species. Connecting forms were common. The plants from Lone Pine Cañon, which Abrams (Bull. N. Y. Bot. Gard. 6: 407, 1910) cites under *R. cuspidata* Greene, are the same. Lower Transition Zone. (No. 1709.)

Rhamnus crocea Nutt. var. *ilicifolia* (Kell.) Greene. Occasional on dry sunny slopes throughout the Transition Zone. One plant was noted at 8250 ft. alt. on the steep south face of Ontario Peak.

Ceanothus integerrimus H. & A. Quite common in the Lower Transition Zone on the north side of the mountain. Rare in the pine belt on the south side, but abundant in the Upper Chaparral.

Ceanothus divaricatus Nutt. Abundant in the Upper Chaparral Belt, from which it usually extends well up into the Lower Transition Zone. (No. 1577.)

Ceanothus cordulatus Kell. Very common in the Transition Zone on the north side of the mountains, 6000–8000 ft. alt.; not found on the south side although it reaches the dividing ridge crest. (No. 1424.)

Ceanothus greggii Gray. A large colony under the pines, 6600 ft. alt., in North Fork Lytle Creek. Lower Transition Zone. A common Upper Sonoran shrub of the desert borders. (No. 1668.)

STERCULIACEÆ

Fremontia californica Torr. Scarce in the pine belt in San Antonio Cañon; in Prairie Fork it is common and becomes a small tree.

MALVACEÆ

Malvastrum Fremontii Torr var. *orbiculatum* (Greene) Johnston, comb. nov., *M. orbiculatum* Greene. A few scattered shrubs were found on the broad open gravelly floor of Prairie Fork, Lower Transition Zone, 5000–6750 ft. "Swartout Valley" acc. Abrams (Bull. N. Y. Bot. Gard. 6: 418, 1910).

Our plants differ from *M. Fremontii* chiefly in their less densely woolly calyces and in their shorter bracts. *M. Davidsonii* does not appear distinct. (No. 1673.)

VIOLACEÆ

Viola purpurea Kell. var. *pinetorum* Greene. A common and widely distributed plant within our limits. We have observed it from 4500 ft. alt. in the Upper Chaparral Belt up to 9660 ft., in the Canadian Zone, on Pine Mt. Summit. Mrs. Wilder (No. 593) obtained specimens on the summit of Baldy. Usually growing in dry ground under the pines. (Nos. 1281, 1760, 1734.)

LOASACEÆ

Mentzelia lævicualis T. & G. Dry sandy ground on both sides of the mountain. Very abundant in both Prairie Fork and North Fork Lytle Creek. Collected also in the Upper Transition Zone at 8000 ft. at the Old Gold Ridge Mine.

Mentzelia dispersa Wats. *M. pinetorum* Heller. Frequent in dry sunny ground in the Transition Zone. It was found most abundantly on the south side of the mountain where it was also collected in the Upper Chaparral Belt. This determination, as in the following Menzelias, is by Mr. Macbride. (Nos. 1602, 1694, 2090.)

Menzelia albicaulis Dougl. var. *Veatchiana* (Kell.) Urb. & Gilg. Frequent along the lower edge of the pine belt. Very common on Brown's Flats. (No. 1755.)

Menziesia empetrifolia T. & G. var. *Davidsoniana* Abrams Macbr. But a single colony of this was seen. It grew in gravelly ground, in the lower portion of the pine belt, alt. 5750 ft. in Coldwater Fork Lytle Creek. (No. 2059.)

DATISCACEÆ

Datisca glomerata (Presl) B. & H. Occasional in wet ground in the Lower Transition Zone. More common at lower levels.

CACTACEÆ

Opuntia occidentalis Engelm. A common mesa species along the south base of the mountains, which commonly ascends the cañons and becomes frequent on dry, open, sandy cañon floors in the Upper Chaparral Belt. From these situations it often penetrates a short distance up into the Lower Transition Zone.

Opuntia basilaris Engelm. & Bigel. A few plants growing with *Pinus monophylla* at about 6500 ft. alt. in the upper part of North Fork Lytle Creek. Lower part of the Transition Zone.

ONAGRACEÆ

Zauschneria californica Presl, var. *latifolia* Hook. Common in dry ground under the pines, especially in the Upper Transition Zone. (No. 1586.)

Chamaenerion angustifolium Scop. Locally abundant at two station in the Upper Transition Zone; Coldwater Fork Lytle Creek at 7000 ft. alt. and in a small side cañon of Prairie Fork, also at 7000 ft. No. 1396.

Epilobium glaberrimum Barbey. Occasional in springy ground, apparently confined to the Upper Transition Zone. (No. 1600, 2075.)

Epilobium ursinum Parish. The common *Epilobium* of the Upper Transition Zone. Det. S. B. Parish. (No. 1664.)

Epilobium paniculatum Nutt. A few plants in dry ground at the Native Son Mine.

Gayophytum ramosissimum T. & G. Very common in dry, open ground in the Lower Transition Zone. (Nos. 1482, 1533.)

Gayophytum caesium T. & G. Practically confined to the Upper Transition Zone on the north side of the mountains, extending over to the south side only at the head of San Antonio Cañon. (No. 1695.)

Clarkia rhomboidea Dougl. Dry ground in the lowest parts of the Transition Zone. Very common at the mouth of Icehouse Cañon. (No. 1404.)

Onagra Hookeri (T. & G.) Small. Frequent in damp ground along streams, ascending to 8000 ft. alt. in the Upper Transition Zone.

Sphaerostigma [illegible] Dougl. walp. Occasional in dry sandy ground about the Native Son Mine, alt. 5000 ft.

ARALIACEÆ

Aralia californica Wats. Occasional in moist shaded places in the Lower Transition Zone. Much more common in the Upper Chaparral Belt.

UMBELLIFERÆ

Osmorhiza brachypoda Torr. A foothill species which ranges a short distance up into the pine belt.

Osmorhiza nuda Torr. We know it only from a marsh in a small side cañon of Prairie Fork, alt. 7000 ft., Upper Transition Zone. (No. 2084.)

Deweya arguta T. & G. Lower part of the pine belt in San Antonio Cañon.

Drudeophytum Parishii C. & R. A common plant in dry sunny ground in the Upper Chaparral Belt and Lower Transition Zone. (No. 1476.)

Drudeophytum vestitum (Wats.) C. & R. Dry rocky ground throughout the Transition and Canadian Zons. Very abundant on Baldy Summit where the type was collected by Parish. (Nos. 1260, 1467.)

Lomatium Parishii C. & R. Collected by Parish on "high ridges on Old Baldy Mountain, San Bernardino County" acc. Coulter and Rose (Contr. Nat. Herb. 7:235, 1900). Hall (No. 1442) found the plant in Coldwater Fork, Lytle Creek, at 5500 ft. alt. where it grew "in dry rocky soil."

Leptotenia multifida Nutt. Frequent in rocky ground under the oaks in the lower levels of the Transition Zone, 5200–5700 ft. alt., in Coldwater Fork, Lytle Creek. (No. 2058.)

CORNACEÆ

Garrya Veatchii Kell. var. *Palmeri* (Wats.) Eastw. Abundant in the Upper Chaparral Belt. Occasional shrubs of this species are found scattered through the Lower Transition Zone. Usually in dry, sunny situations. (Nos. 1578, 1579, 1982.)

PYROLACEÆ

Pyrola pallida Greene. Common on moist shaded slopes in the Transition Zone. (Nos. 1478, 1585.)

Chimaphila Menziesii Spreng. Collected but once, on a cool moist north slope in the Upper Transition Zone, alt. 7350 ft. in Icehouse Cañon. We consider the plant rare but it is "frequent in the San Antonio Mts." acc. Abrams Fl. Los. Ang.

MONOTROPACEÆ

Pterospora andromedea Nutt. A rare plant of the Upper Transition Zone. A single plant in the Canadian Zone on Cucamonga Peak Summit. It is most abundant on the rich moist and shaded slopes in the vicinity of Kellys Cabin. (No. 1612.)

Sarcodes sanguinea Torr. Frequent under the pines in the Upper Transition Zone. (No. 1611.)

ERICACEÆ

Arctostaphylos Parryana Lemmon. Frequently in dry ground throughout the Lower Transition Zone. (Nos. 1575, 1576.)

Arctostaphylos patula Greene. Dry ground under the pines in the upper parts of the Transition Zone and in the Canadian Zone. The range of this species coincides almost exactly with that of Castanopsis. (Nos. 1540, 1580.)

Arctostaphylos pungens H. B. K. We know of two large colonies of this species in the San Antonio Mts. both of which extend a short way into the pine belt. One colony is on the Baldy Trail just above Bear Flats, 5700–6500 ft. alt., the other colony is on the south spur of Cucamonga Peak above what is known as Manzanita Flats, alt. 6200–6700 ft. This species is recognized readily by its very dark, mahogany-colored bark. (No. 1468.)

PRIMULACEÆ

Dodecatheon Jeffreyi Van Houtte var. *redolens* Hall. One of the interesting discoveries in a small marsh which is located in a side cañon of Prairie Fork. The marsh has rather a steep pitch, and as a result there are several well defined drainage channels in which the water comes nearer to the surface and the dense growth of fireweed and grasses is broken. In these mossy, water-saturated lanes this *Dodecatheon* grows. With it are *Carex aurea celsa, C. subfusca, Juncus Mexicanus, Sisyrinchium orcophilum* and *Trifolium monanthum Grantianum*. The plant was devoid of any odor. The mouth of the side cañon in which the marsh is located is marked by a large, red, U. S. F. S. tool-box. The marsh is at 7000 ft. alt. in the Upper Transition Zone. (Nos. 1648, 2100.)

GENTIANACEÆ

Frasera neglecta Hall. The type of this species was collected by Dr. Hall (No. 1495) at the head of Swartout Cañon, San Antonio Mts., 6900 ft. alt.

APOCYNACEÆ

Apocynum cannabinum L. Occasional in moist ground in the Transition Zone. (No. 1661.)

Cycladenia humilis Benth. Occasional on dry exposed slopes on all the peaks. Upper Transition and the lower part of the Canadian Zone. Reaching its maximum altitude at 9000 ft. (Devils Backbone). Always found in small colonies. (Nos. 1428, 1431, 1550.)

ASCLEPIADACEÆ

Asclepias eriocarpa Benth. A few plants at 7000 ft. alt. on a dry sunny cañon side, Upper Transition Zone, in San Antonio Cañon.

Asclepias californica Greene. Occasional in dry ground under the pines in the Lower Transition Zone. (No. 1266.)

CUSCUTACEÆ

Cuscuta californica Choisy. Not uncommon on *Eriogonum* and *Chrysothamnus*. Seen as high as 8000 ft. No. 1686.

POLEMONIACEAE

Phlox Douglasii Hook. Summit of Swartout Cañon, 6800 ft. alt. *Hall 1529.*

Gilia pungens Benth. var. *tenuiloba* (Parish) Milliken. Common in rock crevices, ranging from the lower edge of the Transition through the Canadian Zone to Baldy Summit. Usually grows with one of the two *Heuchera* species. (Nos. 1265, 1411, 1418, 1621.)

Gilia latiflora Gray var. *exilis* Gray. An abundant species on dry open pine-clad slopes in the Transition Zone. (Nos. 1265, 1547.)

Gilia tenuiflora Benth. var. *altissima* Parish. A common species in the chaparral belt which ascends a short distance into the Transition Zone. (No. 1743.)

Gilia densifolia Benth. Very common in dry rocky ground in the Lower Transition Zone. (Nos. 1385, 1459, 1587).

Linanthus ciliatus (Benth.) Greene. Frequent in dry rocky ground in the Lower Transition Zone.

Linanthus concinnus Milliken. Dry rocky ground in the Lower Transition Zone, alt. 5700 ft., in Icehouse Cañon. In crevices of granite on the west end of Ontario Peak, alt. 5000 ft. The type of the species was collected by Hall "on the trail to Mt. San Antonio, alt. 6100 ft." (Bot. Gaz. 31: 389, 1901.) No. 1284

HYDROPHYLLACEAE

Phacelia curvipes Torr. Frequent in dry ground in the Transition Zone. Seen in the Canadian Zone at 9000 ft. alt. on the Devils Backbone and on Telegraph Peak Summit. (Nos. 1414, 1592, 1603.)

Phacelia curvipes Torr. var. *pratensis*. All my collections were of the small flowered typical plant but Dr. Hall collected in Swartout Valley the large flowered form that is referred to this variety by Brand (Pflanzenr. IV, 251 : 115 (1913).

Phacelia hispida Gray. Under the pines at 6000 ft. alt. in San Antonio Cañon.

Phacelia ramosissima Dougl. var. *suffrutescens* Parry. Locally abundant on the broad, open cañon floor of Prairie Fork, 6500–7000 ft. alt., Lower Transition Zone. (No. 2091.)

Phacelia longipes Torr. Frequent throughout the Transition Zone but especially abundant in the lower part of Icehouse Cañon. (Nos. 1285, 1535.)

Phacelia mohavensis Gray. Swartout Valley at 6000 ft. alt. *Hall 1501.* Det. by Brand.

Phacelia mohavensis Gray var. *exilis* Gray. "North side of the San Antonio Mts. *Hall 1260* acc. Brand (Pflanzenr. IV. 251 : 123 (1913)

Phacelia Davidsonii Gray. Occasional in dry ground in the Lower Transition Zone. (Nos. 1264, 2034.)

Phacelia Davidsonii Gray. Form *macrantha* (Parish) Johnston, comb. nov. *P. Davidsonii* Gray. var. *macrantha* Parish. We did not see any plants that were referable to this large flowered form but according to Brand (Pflanzenr. iv. 251 : 116 (1916)) Dr. Hall collected it in our limits.

The plant concerned here differs from typical *P. Davidsonii* only in its large flowers (15–22 mm. wide). As there appears to be no relation of distribution with the occurrence of this variation and since a very com-

plete gradation exists between the extremely large and extremely small flowered plants we have thought it best to treat this plant as a "form."

Phacelia Fremontii Torr. *P. Hallii* Brand. Collected by Dr. Hall as high as 7000 ft. alt. on the north side of the mountain.

The type of *P. Hallii* came from 6700 ft. alt. on the north side of the mountain. The slightly smaller flowers are the only difference that I can detect between specimens of the type collection (*Hall 1264*) and other collections from Swartout Valley (*Hall 1494*) that Brand has passed as *P. Fremontii*. I have also seen a collection referable to *P. Hallii* from 7000 ft. alt. (*Hall 291*).

Eriodictyon trichocalyx Heller. Dry sunny open slopes up to an altitude of 9000 ft. Usually associated with *Rhamnus californicus*. (No. 1574.)

Turricula Parryi (Gray) Macbr. A few scattered colonies were found in sunny rocky ground in the Transition Zone. On the south side of the mountain it is more common and reaches greater size in the Upper Chaparral Belt. (No. 1564.)

BORAGINACEÆ

Cryptantha ambigua (Gray) Greene. Frequent in dry, sunny ground throughout the Transition Zone, alt. 5000–8200 ft. Det. by Mr. J. F. Macbride. (Nos. 1620, 2035, 2057, 2071.)

Cryptantha muricata (H. & A.) Nels. & Macbr. Frequent in dry ground, mainly in the Transition Zone. A reduced form with stems averaging under 6 mm. high was found on Telegraph Peak Summit, alt. 9000 ft. (Nos. 1542, 1598.)

Cryptantha muricata (H. & A.) Nels. & Macbr. var. *Jonesii* (Gray) Johnston, comb. nov. *Krynitzkia Jonesii* Gray. Most abundant in the chaparral belt but occasionally found under the pines in the Lower Transition Zone.

In its typical form this plant is separated from the last by its somewhat larger flowers and strict habit of growth. Numerous intermediate stages exist between these two extremes and so we have assigned *Jonesii* to varietal rank. (Nos. 2073, 2077.)

VERBENACEÆ

Verbena prostrata R. Br. Frequent in dry sunny ground in the Lower Transition Zone. Locally abundant in springy ground, 8000 ft. alt. in the Upper Transition Zone at the Old Gold Ridge Mine. (Nos. 1407, 1608.)

LABIATAE

Pycnanthemum californicum Torr. Moist ground in the lower part of the pine belt; common in the chaparral belt. (No. 1715.)

Monardella cinerea Abrams. Known only from the San Antonio Mountains, where it is found in scattered stations in the Canadian and Transition Zones, invariably growing in rocky situations. A ledge of rock, well shattered by the elements, is its favorite location.

The type station is "near the summit of Mt. San Antonio." The plant is most abundant on the very rocky, gentle south slope of Little Baldy, Cana-

dian Zone at 9500 ft., and no doubt the type was collected there. The species does not grow on Baldy Summit for it reaches its upper limits at about 9700 ft. alt. The lowest station noted for the plant was at 6000 ft. alt. on the Baldy Trail just above Bear Flats where it grows on the border line between the chaparral and pine belt. At this low station the plant was in flower during the first of July while on Little Baldy it was not in full bloom till the last of August. (Nos. 1261, 1420, 1421, 1422, 1449, 1549, 1571, 1693.)

Monardella linoides Gray var. *stricta* Parish. This was collected in Swartout Valley between 6000 and 8000 ft. alt. at various times by Dr. Hall.

Salvia apiana Jeps. An occasional entrant into the pine belt. Seen as high as 8000 ft. alt. An abundant species on the mesas along the south base of the mountains.

Scutellaria angustifolium Pursh. Collected by Dr. Hall (No. 1251.) on the north base of the mountain at 5600 ft. alt.

Stachys albens Gray. Occasional in moist ground in the Lower Transition Zone. In the Upper Transition Zone, alt. 8000 ft., at the Old Gold Ridge Mine. (No. 1604.)

SOLANACEÆ

Nicotiana Bigelovii Wats. A few plants along the trail at 5400 ft. alt. in Icehouse Cañon.

Solanum Xantii Gray. Frequent in shaded ground in the Lower Transition Zone.

SCROPHULARIACEÆ

Collinsia Childii Parry. Locally abundant on moist, cool, shaded cañon-sides at 4500 ft. alt. in Cascade Cañon. Lower Transition Zone. (No. 1282.)

Collinsia callosa Parish. The type of this species was collected by Hall in Swartout Valley. Dr. Hall collected other specimens at 6500 ft. alt. in Lytle Creek.

This species may be only a coarse xerophytic form of the last species. It differs from *Childii* in being stouter, lower and in having shorter, stiffer and more widely spread branches. Its leaves are shorter, broader, thicker in texture and nearly sessile. The calyx is twice as broad, square at the base, and with thick, nearly deltoid calyx lobes which have barely apparent midribs. These characters coupled with its general distribution, which consists of the desert slope of the San Antonio Mts. and the various small mountains of the Majove Desert, would make the aforementioned relationship to *C. Childii* at least plausible.

Collinsia Torreyi Gray var. *Wrightii* (Wats.) Johnston, comb. nov. *C. Wrightii* Wats. *C. monticola* Davids. Colonies of this plant are frequent under the pines in the upper part of the Transition Zone and in the Canadian Zone. Its range seems to coincide with that of *Castanopsis*. The highest station that we know for this interesting little plant is at 8700 ft. alt. on the saddle between Baldy and Pine Mt., but Davidson cites under his species a collection by Mr. Burlew from Baldy Summit. We have seen a collection by Dr. Hall (No. 1239) from near the summit of Baldy at 9700 ft. alt. The plant

is exceedingly abundant under the pines in the vicinity of Kellys Cabin, 8000–8500 ft. alt., where it colors the ground in the openings between the manzanita and chinquapin bushes.

C. monticola was based on collections made by Dr. Hall at 6800 ft. alt. in Swartout Valley. This species, however, is an exact duplicate of Sierran *C. Wrightii*. The only character which distinguishes *Wrightii* from *C. Torreyi* is its smaller sized corolla. This character, while apparently constant, is, in our mind, not sufficient to warrant the separation of these two very closely related forms. (No. 1551.)

Mimulus glutinosus (Nutt.) Wendl. var. *brachypus* Gray. Occasional in dry, sunny, rocky places along the lower edge of the pine belt. A large colony was found on a dry sunny slope at 7500 ft. alt. in the lower part of the Upper Transition Zone in North Fork San Antonio Cañon. (No. 1607.)

Mimulus Palmeri Gray. Collected by Dr. Hall. (No. 1449.) at 5800 ft. alt. in Lytle Creek Cañon.

Mimulus Fremontii. Lytle Creek Cañon, alt. 6000 ft. *Hall 1543*.

Mimulus sp. A small red *Mimulus* (*Eunanus*) is common in dry ground under the pines. It extends from the lower edge of the pine belt up to 9700 ft. alt. in the Canadian Zone on Little Baldy.

Its nearest relative appears to be *M. Fremontii* but it has smaller flowers and has a single, erect, pubescent much coarser stem which is evenly branched from base to summit and not restricted to basal branching as is the more slender stemmed *Fremontii*. Its calyx is less distinctly angled, apparently shorter and much less constricted at its mouth. The leaves are much more numerous, thicker, broader and decidedly pubescent. (Nos. 1486, 1524.)

Mimulus floribundus Dougl. Frequent in moist ground. Seen at 7000 ft. alt. in Coldwater Fork Lytle Creek.

Mimulus rubellus Gray. A few plants in moist ground at 6500 ft. alt. in Middle Fork Lytle Creek. Specimens too poor for positive determination. Plentiful collections of this species were made, however, by Dr. Hall (No. 1458) at 6000 ft. alt. in "Lytle Creek Cañon." (No. 1618.)

Mimulus microphyllus Benth. A small depauperate form of apparently this species is quite common in the springy ground at the Old Gold Ridge Mine, Upper Transition, alt. 8000 ft. (No. 1599.)

Mimulus cardinalis Dougl. Common in moist ground throughout the Transition Zone. (No. 1524.)

Pentstemon labrosus Hook. Common under the pines in the Transition Zone. (Nos. 1460, 1461, 1557.)

Pentstemon Palmeri Gray. Frequent under the pines in the Transition Zone. Seen in the Canadian Zone, alt. 9000 ft. on the Devils Backbone. It extends some distance down into the Upper Chaparral Belt where it is common at 3500 ft. alt. on Hog Back. (No. 1526.)

Pentstemon ternatus Torr. Most common in the Upper Chaparral Belt, but not uncommon in the lower part of the pine belt. (No. 1676.)

Pentstemon centranthifolius Benth. Common on the broad sandy floor of Prairie Fork, ascending the cañon to over 6000 ft. alt.

Castilleja miniata Dougl. Springy ground in the Upper Transition Zone. Not uncommon on the north side of the mountain, but on the south slope it

is known only from 8000 ft. alt. at the Old Gold Ridge Mine. The highest we collected the plant was at 8750 alt. on the saddle between Baldy and Pine Mountain. (No. 1380, 1527.)

Castilleja Martini Abrams (?) Here we doubtfully place the common *Castilleja* which grows in dry, sunny ground in the Transition Zone. (Nos. 1383, 1700.)

Cordylanthus Nevinii Gray. Not uncommon under the pines in the Upper Transition Zone. (No. 1662.)

Cordylanthus rigidus (Benth.) Jeps. var. *filifolius* (Nutt.) Macbride. Common in dry ground below 6500 ft. alt. (No. 1675.)

Pedicularis semibarbata Gray. Moist shaded ground under the pines, especially in the upper part of the Transition and lower part of the Canadian Zone. In the upper part of Icehouse Cañon, alt. 8000–8250 ft., the plant is very abundant, nearly carpeting the ground with its fern-like foliage. Collected in the Lower Transition Zone at 6000 ft. alt. in South Fork Lytle Creek and at 7000 ft. alt. at the Baldy Lookout. The maximum altitude seen was 8700 ft., at that altitude it was collected on the east slope of Baldy. (Nos. 1274, 1455.)

OROBANCHACEÆ

Orobanche californicum C. & S. On *Eriodictyon* at 9000 ft. alt. in the Upper Transition Zone on the Devils Backbone. (No. 1762.)

Thalesia fasciculata (Nutt.) Britton. Frequent on *Eriodictyon*, ascending to 9000 ft. alt. (No. 1556.)

Bochniakia strobilacea Gray. Common in the chinquapin belt in all parts of the mountain. It is almost unbelievable to us that this plant has been considered a rarity. On every trip, which we made into the mountains above 8000 ft., we have seen literally hundreds of plants. It was most abundant on the south slope of Telegraph Peak, for there the plants grew in dense clusters of thirty or more individuals. These dense masses of plants, due to their growth, caused the upheaval of numerous small areas, the majority of which were a meter in diameter. The condition on Telegraph Peak, however, was not typical of the rest of the mountain. In most parts of the mountain the plants grew singly and were freely scattered over the area which the colony occupied. The favorite host appears to be *Arctostaphylos patula*. At 6500 ft. alt. on the south slope of Baldy it was collected on *A. Parryana* while at 5200 ft. alt. in the Upper Chaparral Belt on the south spur of Cucamonga a few plants were noted on *A. tomentosus*. The most peculiar thing noted about the plant was that only those flowers which remained underground, two thirds of the inflorescence doing so, matured their fruit. The part of the inflorescence which projects above ground is infertile and has a resemblance to a tama rack pine cone. (Nos. 1432, 1449, 1554, 1555.)

RUBIACEÆ

Galium multiflorum Kell. var. *parvifolium* Parish. Common among the rocks on Baldy above 9000 ft. alt. A single plant was collected at 7750 ft., Upper Transition Zone, at the Old Hydraulic Mine. This single plant was the only one seen outside of the Canadian Zone. (Nos. 1398, 1691, 1698.)

Galium Aparine L. Moist shaded ground in the lower portions of the Transition Zone.

Galium siccatum Wight. (?) We very doubtfully place here the common *Galium* of the pine belt. The plant is very common in dry rocky ground throughout the Transition Zone, reaching its maximum elevation at 8700 ft. alt. on Ontario Peak Summit.

Our plant is not "suffrutescent" nor is it "branched and bushy." It is a tufted perennial with the low (under two decimeters in height), erect, herbaceous stems unbranched. The other characters of the plant agree very well with *G. siccatum* as described, but its reference to this species is, however, very unsatisfactory. In recent years this same plant has been referred to *G. multiflorum* Kell. (Nos. 1262, 1591, 1615.)

Galium angustifolium Nutt. A very interesting form of this species is common in the lower portion of the pine belt and higher parts of the chaparral belt on the south side of Cucamonga and Ontario Peaks. Due, no doubt, to the effects of frost the plants have developed a base of the slender woody stems. From this base the annual growth of unbranched stems arise two or three decimeters. This habit of growth is very different from the taller and very bushy plant of the mesas at the foot of the mountain. We have observed this low form only between 5000 and 7000 ft. alt. (No. 1483.)

Galium sp. An undescribed species of the *G. multiflorum* group is locally abundant in gravelly ground, 5000–5700 ft. alt., at the lower edge of the pine belt in Coldwater Fork Lytle Creek. It was collected at this same station by Dr. Hall. (No. 1227).

The plant is characterized by its long reclining woody stems, its peculiar light color, the very harsh scabrous pubescence, the large semibaccate, densely hirsute fruit and especially by its short lateral branches that bear only a few flowers on their drooping tips. (Nos. 1667, 2067.)

CAPRIFOLIACEÆ

Sambucus glauca Nutt. var. *velutina* D. & H.) Johnston, comb. nov. (*S. velutina* D. & H.) Frequent in moist ground in the Upper Transition Zone.

S. velutina was originally described as having pubescent leaves. Our plants of it, however, are very variable in respect to pubescence. We have noted all gradiations between forms with a dense soft short pubescence and forms entirely glabrous, the latter state being far the more common. The cymes of our plant are very large, being 2–2.5 dm. wide. This fact, coupled with the shrubby growth and larger leaves, serves very well to distinguish this variety from the species. The fruit has a very decided bloom, thus making it impossible to refer our plant to that uncertain species, *S. racemosa* Presl. (Nos. 1537, 1549.)

Symphoricarpus Parishii Rydb. Locally abundant in scattered stations. The stations are as follows, Coldwater Fork Lytle Creek, Upper Transition Zone, alt. 7000 ft., in springy ground with *Salix flavescens* and *Prunus demissa*. South Fork Lytle Creek, Lower Transition Zone, alt. 6000 ft. as a weak prostrate shrub under the pines with *Populus* and *Symphoricarpus*. South spur of Cucamonga Peak, alt. 8000 ft. and on the west end of Ontario Peak, alt. 7000

ft. in dry, sunny, rocky situations in the Upper Transition Zone with *Eriogonum fasciculatum polifolium* and *Gilia pungens tenuiloba*. West spur of Baldy, Canadian Zone, alt. 9000 ft., in dry rocky ground on a sunny ridge with *Eriogonum microthecum* and *Ceanothus cordulatus*. Swartout Valley, alt. 6500 ft. acc. Abrams (Bull. N. Y. Bot. Gard. 6: 457, 1910). (Nos. 1389, 1472, 1727.)

Lonicera subspicata H. & A. A foothill species which reaches 6500 ft. alt. in the Lower Transition Zone.

Lonicera interrupta Benth. Occasional along the lower border of the Transition Zone in Prairie Fork. Reaching 5000 ft. alt. (No. 1713.)

COMPOSITÆ

Brickellia californica Gray. Frequent in dry sunny ground throughout the Transition Zone. Reaching 8000 ft. alt. (Nos. 1536, 1642.)

Brickellia microphylla Gray. Frequent in gravelly ground in San Antonio Cañon and in North Fork Lytle Creek.. A Lower Transition plant which occasionally descends into the Upper Chaparral Belt as at Camp Baldy, alt. 4500 ft. The maximum altitude noted was 6500 ft. Det. B. L. Robinson. (No. 1643.)

Chrysopsis villosa (Pursh) Nutt. var. *fastigiata* (Greene) Hall. Common in dry ground in the Lower Transition Zone. (No. 1701.)

Solidago confinis Gray. Wet ground at the Native Son Mine, alt. 5000 ft. Lower Transition Zone. (No. 1674.)

Solidago californica Nutt. Common under the pines in slightly moist places. Transition and Upper Sonoran Zones. (Nos. 1697, 1710.)

Ericameria cuneata (Gray) McClatchie var. *spathulata* (Gray) Hall. Seen in the pine belt at three stations. At 6500 ft. alt. at San Antonio Cañon Falls, at 6750 ft. alt. in Middle Fork Lytle Creek and at 7000 ft. alt. on the west end of Ontario Peak. Very common on rock ledges in the Upper Chaparral Belt. (No. 1596.)

Chrysothamnus nauseosus (Pall.) Britt. vars. This genus is in the process of revision and so no attempts will be made to give varietal determinations. The common form of this species is abundant in dry sunny ground in the Transition Zone on the north side of the mountain. On the south side shrubs of this species are infrequent and are usually found in the washes at the lower edge of the pine belt. Another form of *nauseosus* represented by my No. 1652 was found growing with the last form on a dry sunny ridge-crest in the Transition Zone, alt. 8000 ft., on Pine Mt. Ridge. It is distinguished from the last form by its long, slender erect stems that are abundantly tomentose and by the very loose inflorescence. (Nos. 1652, 1653, 1706.)

Chrysothamnus viciniflorus (Hook.) Nutt. var. *tortifolius* (Gray) Hall. "Mt. San Antonio" acc. Abrams (Fl. Los. Ang. 366, 1917).

Corethrogyne filaginifolia (H. & A.) Nutt var. *pinetorum* Johnston. Frequent in dry ground under the pines in the Lower Transition Zone. Frequent on open slopes in the Upper Chaparral Belt especially in the region of Sunset Peak. (No. 1644.)

Aster canescens Pursh. A discoid form, which has also been collected in Swartout Valley, Cov. E. H. H. Sept. 1904, is very common in dry rocky ground under the pines, 6000–7000 ft. alt., in Prairie Fork. (No. 1647.)

Aster Menziesii Lindl. A large colony in Prairie Fork about a quarter mile below the Native Son Mine. The plant grew on a sunny but moist bank covering it to the exclusion of all other plants. Lower edge of the Transition Zone, alt. 5000 ft. (No. 1640.)

Erigeron glaucus Hall. Several small colonies were found growing among the loose rocks on the exposed summit of Little Baldy. Canadian Zone, alt. 9550 ft.

This is a very well marked species and is quite distinct from *Leucelene ericoides* to which it was reduced by its author (Univ. Cal. Pub. Bot. 3: 86, 1907). It is separated from all forms of that variable species by its larger hemispheric heads, by its darker and not scarious margined involucre-bracts and by its decidedly broader spathulate leaves. The whole plant is cinerous with coarse, nearly hispid, hairs and is composed of rather few, long, loosely spreading stems. The disk flowers are more numerous and darker in color. The plant has the oblong, obtuse style-branches that characterize both *Leucelene* and *Erigeron;* the general appearance of the plant, however, is very decidedly that of the latter genus.

This species has been collected only in the San Jacinto Mts., the type region, and in the San Antonio Mts. *Leucelene ericoides* is known from California only by a collection made in the Providence Mountains on May 30, 1902 by Mr. Brandegee. (No. 2082.)

Erigeron foliosus Nutt. var. *stenophyllus* (Nutt.) Gray. Frequent in dry sunny ground throughout the Transition Zone. On the upper edge of the Transition Zone at 9500 ft. alt. on Pine Mt. (No. 1682.)

Erigeron divergens T. & G. A single plant growing in wet ground at the Native Son Mine. Collected by Hall in Swartout Valley (Univ. Cal. Publ. Bot. 3: 93, 1907.) (No. 1708.)

Antennaria dimorpha (Nutt.) T. & G. A large colony in very dry rocky ground along the trail in Coldwater Fork Lytle Creek, alt. 6250 ft., Lower Transition Zone. (No. 2060.)

Gnaphalium microcephalum Nutt. Occasional in dry sunny situations in the Transition Zone. (No. 1698.)

Gnaphalium chilense Spreng. Wet ground at the Native Son Mine.

Helianthus gracilentus Gray. Frequently found under the pines in the lower portions of the Transition Zone. Reaching 6000 ft. alt. (No. 1457.)

Hemizonia Wheeleri Gray. Abundant under the pines at 6000 ft. alt. in South Fork Lytle Creek. Lower Transition Zone. (No. 1475.)

Eriophyllum confertiflorum (DC.) Gray var. *trifidum* (Nutt.) Gray. Frequent under the pines, mostly in the Lower Transition Zone. Not detected in the San Antonio Cañon watershed, where it is replaced by the next variety. (No. 1452.)

Eriophyllum confertiflorum (DC.) Gray var. *discoideum* Greene. Noted only in the San Antonio Cañon watershed where it is common in dry ground under the pines in the Transition Zone, ranging from 5000–8000 ft. alt.

Though usually the rays are absent, plants are not uncommonly found which are wholly or partially radiate. These radiate forms are easily separated from the var. *trifidum* by their robustness and by their much broader heads. (No. 1405.)

Chaenactis santolinoides Greene. Frequent in dry ground under the pines in the Lower Transition Zone. (No. 1489.)

Hulsea heterochroma Gray. Seen twice, both stations being in the watershed of Middle Fork Lytle Creek. Cucamonga Peak (Kellys Mine) alt. 8000 ft. and in the Middle Fork at 6750 ft. alt. At the first station there was a very large colony but at the other station only a few plants. (Nos. 1567, 1610.)

Helenium Bigelovii Gray. Very common in springy ground in the Transition Zone. (No. 1525.)

Artemisia dracunculoides Pursh. Occasional in dry round in the Transition Zone. (No. 1660.)

Artemisia heterophyllus Nutt. Frequent in wet ground in the Lower Transition Zone. Much commoner at lower levels.

Artemisia tridentata Nutt. Very common in dry ground in the Lower Transition Zone on the north side of the mountain, but not known to occur on the south side. Noted at 8000 ft. alt.

Artemisia Ludoviciana Nutt. Common in Prairie Fork and on the ridges surrounding it, also in the higher part of North Fork Lytle Creek. Dry ground under the pines throughout the Transition Zone, alt. 6000–8500 ft.

Very variable in pubescence and in habit. Some plants are permanently tomentose above, although much less so than below, while other plants are glabrate above. All our plants, however, agree in having the leaves pinnately cleft into narrow lobes. Dr. Rydberg has determined our No. 1651 as *A. diversifolia* Rydb. (No. 1651.)

Lepidospartum squamatum Gray. Occasionally found in the lower portions of the Transition Zone, usually dry sandy cañon beds. (No. 1717.)

Tetradymia canescens DC. Quite common throughout the Transition Zone on the north side of the mountain. Two plants were noted on the south spur of Telegraph Peak, the only noted station on the south side. Several shrubs grow by the summit cairn on Pine Mountain and therefore at an altitude of 9660 ft. alt. (Nos. 1545, 1672.)

Senecio ionophyllus Greene. (*S. sparsilobatus* Parish. *S. bernardinus* Greene.) This very variable species is frequent under the pines on shaded north-facing slopes, especially in the Upper Transition Zone. It was noted chiefly on the side of the mountain facing the desert, only noted on the south slope of the mountain in Cascade Fork of San Antonio Cañon.

The most common form of the plant is f. *sparsilobatus* (Parish) comb. nov. This form, and several others which, although not altogether typical, are best referred here, is predominating in all the colonies of the plant which we have seen. The orbicular-leaved plant that is referable to typical *S. ionophyllus* and the densely tomentose, f. *bernardinus* (Greene) comb. nov. were both found to be rather uncommon. (Nos. 1381, 1658, 2042, 2076, 2085.)

Senecio triangularis Hook. Several large clumps in a marsh in a side cañon of Prairie Fork. Upper Transition Zone, alt. 7000 ft. (Nos. 1679, 2088.)

Senecio Douglasii DC. Lower edge of the pine belt at 5000 ft. alt. in Prairie Fork. (No. 1678.)

Cirsium Californicum Gray var. *bernardinum* (Greene) Macbride. Occasional on the dry sandy floor of Prairie Fork in the Lower Transition Zone. Ascending to 7000 ft. alt. (No. 1707.)

Anisocoma acaulis Gray. A single plant under the pines, alt. 8000 ft. in the Upper Transition Zone on the divide at the head of San Antonio Cañon. This is perhaps the same station where Dr. Hall (No. 1265) collected the plants which grew on an "open ridge at 8000 ft. alt." (No. 2081.)

Stephanomeria runcinata Nutt. Occasional in rocky ground in the lower and dryer parts of the Transition Zone. Frequent at lower levels. (Nos. 1573, 1649.)

Stephanomeria cichoriacea Gray. Frequent in dry rocky ground in the chaparral belt and in the Lower Transition Zone. Seen in the Upper Transition Zone at 8000 ft. alt.

Stephanomeria virgata Benth. A low, very slender form of this species was common under the pines in the Upper Transition Zone near the head of Prairie Fork. (No. 1654.)

Troximon retrorsum (Benth.) Greene. Frequent in open ground in the Upper Chaparral belt and in the Transition Zone. On Pine Mountain Ridge a colony was noted at nearly 9000 ft. alt. (No. 2089.)

Crepis nana Richards. "On the eastern side of Mt. San Antonio some three or four hundred feet below the summit, near a small snow field, along the Glen Ranch Trail," acc. Burlew (Bull. So. Cal. Acad. 16: 13, 1917).

Crepis acuminata Nutt. Frequent in Prairie Fork and on the ridges surrounding it. Growing in dry rocky ground in the Transition and lower parts of the Canadian Zone. 6000–8500 ft. alt. (Nos. 1650, 2083.)

Hieracium albiflorum Hook. Frequent under the pines; most common in the Lower Transition Zone. (Nos. 1480, 1614.)

Hieracium horridum Fries. In rocky ground in the Lower Transition Zone, alt. 6000 ft., in Middle Fork Lytle Creek. In the Upper Transition Zone at 7000 ft. alt. in Icehouse Cañon and in Cascade Fork San Antonio Cañon. Very common among the rocks, at the upper edge of the Transition Zone, on the summit of Ontario Peak, alt. 8200 ft. (Nos. 1613, 1616.)

BOOKS AND CURRENT LITERATURE

Physiological Problems of Photosynthesis.—A recent paper[1] presents the results of a comparative study of the photosynthetic activities of lowland (276 meters) and alpine (1709 meters and 2456 meters) plants. This paper is interesting not only because of the decided differences that were found in the behavior of plants from these two types of habitat but perhaps even more because it leaves the reader with the conviction that, in spite of the assurance with which the subject of photosynthesis is usually presented, very little is really known regarding this fundamentally important problem of plant physiology. In spite of the more general interest in the purely chemical aspects we are as much in the dark regarding the chemical steps in the process as we were in 1870 when Baeyer proposed the formaldehyde hypothesis. Willstätter's researches have cleared up much that was confusing regarding the organic chemistry of the leaf pigments but they have done practically nothing directly to solve the more important physiological problems except to give the physiologist tools with which to work. Much excellent investigation has been carried on by Blackman and his co-workers upon these latter problems but we are far from knowing even the conditions without and within the plant that are usually influential.

Our ignorance of the measurements that should be made upon the plant and its surroundings in a photosynthetic research is well illustrated by the author's discussions of the problems encountered. These include: the amount of chlorophyll in the leaves; diurnal variations in the amount of chlorophyll; the use of fresh weight or dry weight of leaves as the unit of reference in stating the amount of chlorophyll; the ecological character of the plants (the author used chiefly "meadow plants:" *Anthyllis Vulneraria, Bellis perennis, Primula farinosa, Taraxicum officinale;* "plants of the snow ravines:" *Primula integrifolia, Soldanella alpina*); anatomical characteristics of the plants; where and how to take the temperature; methods of measuring the assimilate;

[1] Henrioi, Marguerite, Chlorophyllgehalt und Kohlensäure—Assimilation bei Alpen—und Ebenenpflanzen. Verhand. Naturforsch. Gesell. Basel. **30**: 43–136. 1918.

variations in carbon dioxide content of the air; method of conducting air to the plants; variations in respiratory activity; use of fresh weight, dry weight, surface or volume of leaves as the proper unit of reference in stating the amount of photosynthate; use of detached leaves or the entire plant as experimental material; character and quantity of light; influence of the plant's content of water and of nutrient salts; influence of leaf exposure and of weather, especially the influence of atmospheric electricity; behavior of stomata during experimentation.

That different kinds of plants have different effective characteristics might perhaps have been expected, although it is only rarely taken into account. That individuals of the same species behave decidedly differently when taken from widely different habitats and examined under the same conditions (the author used three experimental stations having the altitudes given above) is evidenced by the following taken from the author's summary: lowland meadow plants have considerably more chlorophyll than alpine individuals of the same species (often 230% of the latter); plants of the snow ravines have exceptionally high chlorophyll contents (often 350% of the alpine meadow plants); cultivation of the alpine meadow plants in lowland stations during several weeks produced no change in chlorophyll content; alpine and lowland plants of four genera reacted *specifically* toward large changes in character and quantity of light; diurnal variations in chlorophyll content were never found; alpine plants require more light than do lowland plants to assimilate carbon actively, although they do so at much lower temperatures than the latter; in very strong light alpine plants assimilate more rapidly than lowland plants; in very weak light they assimilate more rapidly than the latter only if the temperature is sufficiently low; each species investigated behaved characteristically in its assimilatory activities; near sunset, when the red rays predominate, alpine plants assimilate more rapidly than do lowland plants; when blue light predominates the lowland plants are the most active; before storms the alpine plants assimilate more rapidly than lowland plants, indicating a different reactive ability toward atmospheric electricity.

Some of the results are not in accord with some usually accepted physiological generalizations. It appears that chlorophyll content is more constant when reckoned on fresh weight of leaves than when reckoned on dry weight; amount of photosynthate is more constant when reckoned on leaf volume than on leaf area; high respiratory activity of individuals is associated with high assimilatory activity; small plants of a species assimilate more rapidly than do large plants; respi-

ration of the entire plant must be considered and not merely that of the leaves; assimilation during winter is much more active than under the same conditions in summer, as Miss Matthaei found also. By using entire plants and outdoor air the author obtained assimilation values that were much higher than those of Blackman, Matthaei or Brown and Escombe, but which agree well with those of Thoday who also used entire plants outdoors. The statement that the stomatal opening changes in size when the wave length of the incident radiation is changed throws doubt upon the results of previous investigations dealing with the effectiveness of different portions of the spectrum in photosynthesis. It may be mentioned that Ursprung[2] has recently insisted that because of this stomatal behavior the question of the photosynthetic effectiveness of radiation of different frequencies cannot be settled by the use of plants possessing stomata.

The weakest point in the work is, as the author recognizes, the measurement of radiation. Although one of the most important conditions of photosynthesis, radiation has never been measured in any research on the subject in a way to yield real information. The author used an Eder's photometer which is sensitive only in the blue-violet region and guessed at the energy in the red portion. She recognizes the inadequacy of the latter part of the procedure but does not apparently realize that since the photometer had a *curve* of sensitiveness and the light changed *qualitatively*, her results are not even of comparative value in the region to which the photometer was sensitive. For this reason simple photometers are worse than useless for measurements of sunlight—the same reading at different times may not be due to the same amount of energy.

The research is a comparative one throughout, alpine and lowland plants being investigated simultaneously, and from this standpoint the work is excellent. The "theoretical" reasoning is, however, not very convincing on the whole and shows how badly we need information on the main features of photosynthesis.

Perhaps one of the most important inferences to be drawn from the paper is that, as has been found true in physical and physico-chemical research, the organization of a system in which physical and chemical events are expected to occur may be the condition deciding whether and to what degree they *can* occur. The presence or absence of stomata,

[2] Ursprung, A., Ueber die Bedeutung der Wellenlänge für die Stärkebildung, Ber. d. b. Gesell. **36**: 86–100. 1918.

their behavior, the thickness of the leaf, the amount of photosynthate already formed, the amount already stored in other portions of the plant body, whether the leaf tissue is chiefly palisade or chiefly spongy parenchyma, etc. appear from this study to exert considerable influence. —H. E. Pulling.

Morphology of the Cycads.—In a recent paper published in the Botanical Gazette,[1] Sister Helen Angela Dorety, one of Chamberlain's pupils, continues her morphological study of the cycads. The paper deals with *Dioon spinulosum*, a Mexican form unique because of the large size of the ovulate strobilus and ovules. The cotyledons which vary in number from 2 to 4, resemble those of *Ceratozamia* and *Microcycas* in the number of vascular strands. At a point where the cotyledonary strands leave the protostele of the hypocotyl, they are endarch, becoming mesarch in the base of the cotyledon, and exarch near the tip. Girdling is similar to that of other cycads and is very clearly traced in diagrams in the paper. No extrafascicular cambium indicating relation to the polystele of the Cycadofilicales, is present. The primary root is tetrarch changing to diarch as it develops. The paper is clear and concise, and is illustrated with two plates of 28 drawings.—J. G. Brown.

[1] Dorety, Sister Helen Angela. Embryo and Seedling of *Dioon Spinulosum*. Bot. Gaz. 67: 251–256. 1919.

NOTES AND COMMENT

An account of the use and sources of lignum vitae has been contributed to The Scientific American by Prof. Samuel J. Record, of Yale Forest School. This tropical tree received its name in the days of the Spanish explorers, when its wood was erroneously supposed to possess great medicinal virtue. At present the use of this very durable and highly cross-grained wood is almost confined to the lining of shaft bearings in steamships. No other material is found so satisfactory for use in the last or sternmost bearings of the propellor shaft, where the presence of salt water and the impossibility of lubrication would make metal bearings impossible. There is still an adequate supply of true lignum vitae (*Guaiacum*), although much of it is difficult of access, and the same use is less satisfactorily served by Maracaibo lignum vitae (*Bulnesia*), and by the Central American yellow guayacan (*Tabebuia*), which was used for shaft bearings by the Emergency Fleet Corporation during the war.

Prof. John W. Harshberger, of the University of Pennsylvania, has contributed an illustrated paper on the Alpine Fell-fields of Eastern North America to the April issue of the Geographical Review. The nature of these unforested, rocky areas in Greenland, Iceland and the mountains of Europe and South America is discussed and a more detailed description given of the fell-fields near the summit of Mt. Washington. Professor Harshberger holds that differences in the colloquial names applied to prominent plant formations of America and Europe have obscured their actual features of similarity, which can be ascertained only after adequate descriptions have been published.

It is stated by the daily papers that the Michigan Legislature has authorized the use of a portion of the proceeds of a recent issue of highway bonds for the planting of nut-bearing shade trees along the roadsides of that state. Federal and county appropriations are also likely to be obtained for this purpose. The three-fold benefits to be secured from such a plan will doubtless commend it to other states.

Among the papers which will appear in succeeding issues of The Plant World may be mentioned the following: Sunlight and its Measurement, by Howard E. Pulling; The Solution and Fixation Accompanying Swelling and Drying of Biocolloids and Plant Tissues, by D. T. MacDougal and H. A. Spoehr; Effect of Fertilization on the Seed of Jeffrey Pine, by E. N. Munns; Water Content and Temperature as Factors influencing Diastase formation in the Barley Grain, by W. E. Pickler; The Rôle of Temperature in the Determination of the Transpiring Power of Leaves by Hygrometric Paper, by Edith B. Shreve; Native Vegetation as a Criterion of Site, by C. F. Korstian; and The Evidence for a Growth-Inhibiting Substance in the Pear Tree, by H. S. Reed and F. F. Halma.

THE SOLUTION AND FIXATION ACCOMPANYING SWELLING AND DRYING OF BIOCOLLOIDS AND PLANT TISSUES

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The hydration of a colloidal mass whether it be a dried plate of a biocolloid, a dried plant section or a mass of living protoplasts is all but invariably accompanied by the solution or extraction of some of the substances of the colloidal mass. The material found in such extracts will in all cases be determined by the diffusibility of the compounds present. These diffusions encounter highly specialized conditions at the external limits of the protoplasts where a colloidal phase boundary separates the elastic gels and highly viscid emulsoids of the pentosan-protein-lipoid protoplasm from the denser more rigid cellulose-pectose walls enclosing the cells.

Attempts to fix upon the composition of the "semi-permeable" membrane constituted by this important phase boundary have naturally failed, since it is by its very nature unstable, and since it must in every case be the product of the two colloidal masses which come together and the material which comes to the surfaces of the impinging colloidal masses will be determined largely by the character of the protoplasm and of the wall.[1] Such conditions offer fruitful conditions for unprofitable controversies, which it is not proposed to review at this time.

Measurements and analyses of the chemical nature and concentration of compounds which will cause the disruption and displacement of the wall-protoplasm boundary in "true" and

[1] Free, E. E. A colloidal theory of permeability. Plant World, **21**: 141. 1918, and Wodehouse, R. P. Direct determinations of permeability. Jour. Biol. Chem. **29**:453. 1917.

"false" plasmolysis are abundant, while but little attention has been given to a similar state of affairs which results from loss of water by desiccation as externally expressed by the plant in wilting. Some authors hold the view that when extraction reaches a stage marked by shrinkage of a swollen section, it is an indication that the cells are no longer living, but this may not be taken as a criterion. This point, the stage of irreversible desiccation and death by freezing are all relative to changes in colloidal condition, rather than to simple chemical reactions.[5]

In the course of some work on the imbibition and growth of plants the analyses of which show that the water relations of the protoplasm is determined by the pentosan-protein proportion, and that the activities of such living material is not to be simulated by the imbibitional action of the amino compounds of gelatine, attention was paid to the following matters:

a. Extractions from living cell-masses.
b. Extractions or solutions of sections of biocolloids.
c. Acidity of fresh or living tissues.
d. Acidity of desiccated tissues.
e. Swelling of fresh sections.
f. Re-swelling of extracted and dried tissues.
g. Swelling of dried tissues.
h. Repetition of swelling and drying treatments.

These treatments as applied to median slices of maturing joints of *Opuntia discata* grown at Carmel gave measurements as below at 18 C. The flat joints at 10 to 12 mm. in thickness, and the median portion includes but little chlorophyll. Sections suitable for swelling free from any except the smallest fibro-vascular strands are readily procurable.[6]

[5] Lauk, E., Die bedeutung der Elektrolyten fur Quellungsprocess. Biochem. Zeitschr, **37**: Hft. 1 and 2, pp. 15 and 58. 1916, and Osterhout, W. J. V., Respiration after death. Bot. Gaz. **56**: 1918.

[6] All measurements were made by the use of auxographs described in Growth and Imbibition. Proc. Amer. Phil. Soc., **56**: No. 4, p. 329. 1917.

	WATER DISTILLED	CITRIC ACID 0.01N	POTASSIUM HYDRATE 0.01M	POTASSIUM NITRATE 0.01M
Living median slices				
First swelling	11.4%	6.4%	6.6%	9.2%
Above sections dried. Second swelling calculated on basis of original thickness.				
Second swelling	17.5	26.4	24.5	22.4
Dried median slices not previously treated				
First swelling	430	357	315	541
Second swelling after drying of above	430	250	352	541

The thin slices used to obtain the results in the first line, when dried came down to about one-fourth of their original thickness. To have returned to their original dimensions expansions of about 75 to 85% would have been necessary. The lesser swellings indicate that in the first treatment the substances giving the sections their high imbibition capacity had been largely extracted.

On the other hand but little material in addition to water is lost in the dehydration of cell masses by simple drying. The reduction amounts to about three-fourths of the total volume and an even greater proportion by weight. The chief interest centers in the disposition of the electrolytes and amino-compounds which are combined with the more liquid and more solid phases of the colloid of the active cell. The acids, salts and all substances in solution which do not actually crystallize out in the vacuoles would be finally adsorbed by the colloids in a highly concentrated condition. This would have certain effects inclusive of coagulation which would influence the re-hydration of such cell-masses or material, and which would prevent a return to the original or living condition.

If now we turn to the swelling of sections dried directly from the living or fresh condition the increases are seen to bring the material back to a volume less than the original in various solutions, the deficit being greatest in the alkali and least

in the salt. It is notable, however, that only in the acid solution did an extraction take place in consequence of which the sections when dried and rehydrated failed notably to come back to an approximation of the original.

Other preparations were made in which the sections included a portion of the clear parenchyma as well as of the chlorophyllose layer and the epidermis. These were first hydrated, then desiccated and swelled a second time at 16 to 18°C. The increases were as below:

	WATER DISTILLED	CITRIC ACID 0.01N	SODIUM HYDRATE 0.01M	POTASSIUM NITRATE 0.01M
First swelling	225%	225%	281%	287.5%
Second swelling	100	107	87.5	137.5

The first swelling of the dried material agreed with the measurements of the series described above in showing the greatest expansion in the salt, and a greater relative hydration capacity in the alkali than in the first series. The striking feature of this pair of tests however is the notable reduction in hydration capacity of material which had been previously treated. Such reduction obviously can not be ascribed to coagulation, but must be attributed to the effect of extractions, otherwise it would have been shown in the first swelling after drying. This extraction had the greatest effect in the alkali and was not widely different in water, acids and salts. The difference between the behavior of these sections and of the previous pair may be safely attributed to the presence of some diffusible substance affecting imbibition present in the chlorophyllose layer.

That this hypothetical material or combination is however not characteristic of chlorophyll-bearing tissues is shown by the behavior of another Opuntia.

A spineless *Opuntia* from Mexico which had been obtained from Mr. David Griffiths of the United States Department of Agriculture several years previously showed less mucilage than *O. discata* and other forms from Tucson. Dried median slices

came down to a thickness of about 0.2 mm. and these gave swellings at 16°C. as below:

WATER DISTILLED	CITRIC ACID 0.01N	POTASSIUM HYDRATE 0.01M	POTASSIUM NITRATE 0.01M
After first drying			
361%	306%	250%	325%
After second drying			
42%	56%	100%	75%

The dried median slices show a general behavior similar to that of the epidermal slices of the first species, the most important feature being the difference between the first and second swellings. These are very marked and indicate the extraction of some substance which gives a high coefficient of swelling.

The solution of material from a section of a plant with its thousands of cellulose walls presents physical features that are not easily to be duplicated. Amino-acids, hexoses, malates, and salts however constitute the bulk of the extracted material, together with other substances set free by the bursting walls of some of the cells, in addition to those crushed in taking out the section. Diffusion of the pentosans would take place slowly, although the derivation of large proportions of this material by extraction after killing with ether suggests that the rate is not inconsiderable, and may be subject to various modifications.

The lessened hydration capacity of a section previously extracted is probably a resultant of various losses. The salts would operate to limit imbibition of a carbohydrate-protein colloid and their extraction would remove this limit. Free acids limit swelling. Extraction may remove acids and salts which lessen swelling, and at the same time some amino-compounds which give to pentosans a high hydration capacity. The second swelling therefore represents a series of reactions widely different from those of the first treatment.

It was not practicable to make determinations of the extraction of material in all the solutions but attention was given

to the action of distilled water in dissolving out the contents of cells and of the components of colloidal plates, and to estimate the rate and amount of acids dissolved out.

We are indebted to Prof. H. M. Richards for determinations of the acidity of the water in which fresh slices of the Opuntia were swelled and it was found this might be expressed as follows: 10 cc. solution from dish in which set of fresh sections were swelled in water = 0.44 cc. N 20 KOH. Dried slices of the above material when swelled in water twenty-four hours gave a solution the acidity of which might be expressed as: 10 cc. of solution = 0.10 cc. N 20 NaOH. When such sections were immersed in citric acid 0.01N. the strength of the solution was increased so that at the end of twenty-four hours the acidity was expressible as: 10 cc. of solution = 2.25 cc. N 20 NaOH.

The rapid penetration of cell-masses by acids is a well-known reaction and is accompanied or followed by the extraction of electrolytes, and it has been held by some authors that when the preliminary swelling which takes place in acids changes to a shrinkage that death is implied.[1] This last distinction is one without special meaning in connection with the present paper.

The hydration of colloidal plates, of dried sections of plants, and of fresh sections presents parallel reaction in hundredth normal organic acids. The chief features of such swellings consist in an initial rapid expansion followed by shrinkage due to solution or dispersion of the sections.

The swelling of the pentosan, agar, which has been used so widely in the imbibition measurements in connection with growth would be accompanied by the solution or dispersion of material of the external part of the sections and by the diffusion of whatever salts or acids might be present in the interior of the mass. A test was carried out to determine what such loss might be in sections of agar and in a simple biocolloid. The agar was cast in plates which came down to 0.25 mm. in thickness from a 2.5% solution. Sections swelled as follows at 17 to 18°C.

[1] MacDougal, Richards and Spoehr. The basis of succulence. Bot. Gaz., 67: 405. 1918.

WATER	SODIUM HYDRATE 0.01M	POTASSIUM NITRATE 0.01M
2420%	602%	1700%

Strips equivalent to 200 sections with a surface of 2520 sq. mm. were now placed in beakers of distilled water, 10 cc. to each section 12 sq. mm., for a period of twenty-four hours at the same temperature. The evaporation of the water showed 0.2570 gram of material had been dissolved from the plates or sections which weighed 1.6731 gram at the beginning, which was equivalent to about 15%. This proportion is to be contrasted with the 7% of the soluble material dissolved from sections of Opuntia allowing for the non-soluble cell-walls.

Another series of swellings and extractions was made with sections of biocolloids consisting of 8 parts agar and 2 parts gelatine, which were heavier, having a thickness of 0.38 mm. The swellings were as follows at 16°C.

WATER	CITRIC ACID 0.01N	POTASSIUM HYDRATE 0.01M	POTASSIUM NITRATE 0.01M
1684%	947%	474%	1347%

Strips of this material weighing 1.0316 gram with a surface of 2542 sq. mm. were placed in water at temperatures as above for twenty-four hours and when this was evaporated a residue of 0.1865 gram was found, which was equivalent to about 18% of the original. Most of this and of the material dissolved from agar sections in all probability is derived from the surface layer of the material as both gelatine and agar are so nearly non-diffusible as to render their extraction from the interior of the section all but impossible.

A test was arranged to estimate the relative amount of material which might be extracted from plant tissues by a treatment which would parallel the immersions used in obtaining swelling measurements. Sections of joints of Opuntia have been used extensively in work on swelling and in order to obtain sufficient material 24 of the customary size for testing under the auxograph were placed in 250 cc. of water at temperatures

of 16 to 18°C. at which swellings under instruments were also made. At the end of twenty-four hours the mucilaginous solution was measured off, 50 cc. being allotted for acidity determinations (see results above), and 180 cc. was used for determination of the solid matter present. It was found that this amounted to 0.28 gram for the 240 cc. of juice obtained from sections having a total volume of 40 cc. when fresh. The actual solid matter of the sections including the cell walls may be taken as 10% of the whole, or as 4 grams. Of this 7% was dissolved out in water.

The extraction of this amount of material could readily be held to account fully for the changes which take place in hydration and which give different expansions in the second immersion.

According to recent results of Miss E. Grace Stewart, the pentosans which are probably present in all cells in varying proportions are formed in the cytoplasmic mass, and collect in a layer near the wall or in cavities in the protoplasm.[5] The bursting of some cells by imbibition pressure or the crushing of others in preparing the sections allows some of this material to escape in extractions or in swelling.

It is to be noted that we purposely avoid all mention of osmotic action in the obvious sense. Swelling may in the ultimate be due to the increase of internal microns in colloids of plates, of cells and of dried tissues by the adsorption of molecules of water and hence the differential between this increase and the loss by migration and dispersion of salts, acids and colloidal material might be regarded as the resultant of osmosis.

It is quite clear that no explanation of absorption of solutions by cell masses, or of plasmolysis may be adequate or greatly useful which does not take into account certain fundamental mechanical features of the cell-structure. Among these are to be included the phase boundaries of the colloids of the cell wall, of the vacuoles, of the protoplast, and of the multiple and varying structures in the protoplasm. Some recognition of

[5] Stewart, E. G. Mucilage or slime formation in the cacti. Bull. Torr. Bot. Club 46: 157. 1919.

these facts has come from Stiles and Jorgensen,[6] and a fuller estimate of their importance must precede any further profitable discussion of the hydration and water-relations of living matter.

It is to be noted that plasmolysis or decrease in the volume of the protoplast occurs in the immersions and during the extraction of acids from cell-masses, and that it also takes place in wilting. The plasmolytic contraction from the walls may be held in such manner as to be irreversible and the protoplast thus modified may continue to live. Death is therefore not identical with irreversible plasmolysis.

Plasmolysis by osmotic action is accompanied by losses and by penetrations and perfusions of complex character in the many phases of the cell colloids. Plasmolysis in wilting is in some respects a simpler matter. Vaporization of water from the cell-walls is followed by replacement movements from the cell colloids, which result first in a lessened volume of the protoplast and finally in the progressive concentration of all substances, especially those dissolved in the vacuoles, and in the more liquid phases of the colloids. The fact that the acids may be readily extracted in greater proportion from dried specimens than from fresh tissues suggests that these substances may have crystallized out to some extent after the manner of amino-acids incorporated in colloidal mixtures. The same may be true to some extent of the salts. There is also much in favor of the conclusion that changes take place in the colloidal mesh, as a result of a loss of water, and of the action of adsorbed bases which cause coagulations not reversible by simple hydration. Aggregations which may effect the imbibition capacity of or water-relations of masses of protoplasm, especially its external layers or phase boundaries even in the most highly hydrated condition also may occur.

[6] Stiles and Jorgensen. I. Studies in Permeability. Ann. of Bot. **29**: 349. 1915.

The swelling of plant tissue in water and its relation to temperature and various dissolved substances. Ann. of Bot. **31**: July and October, 1917.

EFFECT OF FERTILIZATION ON THE SEED OF JEFFREY PINE

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In May, 1914, the Jeffrey pine (*Pinus jeffreyi*) in the San Bernardino Mountains of Southern California gave promise of a forthcoming seed year, and when this was realized, plans were made to determine the effect of the parents on the seed. To this end, muslin sacks were tied around some of the pistillate flowers on a number of trees; and when the pollen began to be liberated, it was collected in envelopes from the various chosen trees and the flowers were pollinated by the blowing of this pollen onto the cones, care being taken that all portions of the cones were thoroughly dusted. This pollination was done three times at intervals of four days to make sure that all of the flowers were covered, even those that were latest in becoming receptive. When the pollen had ceased flying, the bags were removed from the cones.

The trees chosen for this work are described in the following list (table 1), all the trees being from sixty to one hundred and ten years old, and growing at an elevation of 6000 feet on a south slope and on a deep granitic loam soil. The character of the trees and the low crown facilitated this work, much of it being done from a light ladder.

In fertilizing the flowers the trees were crossed as is shown in table 2. For convenience in reference the number is followed by the character of the tree.

After the cones were collected the following fall, they were sun dried and left to open slowly. The seeds were carefully cleaned by hand and weighed, and the number of seeds to the pound was computed. Each lot was then sown in the nursery the following spring under nursery conditions and all the lots

TABLE 1

Description of trees

1. Very thrifty tree; fast growing; 80 feet high; heavy foilage.
2. Insect-infested tree (*Dendroctonus valens*); otherwise thrifty; tree died in second year.
3. Suppressed tree; 35 feet high; 110 years old; suppressed by other pines and oak (*Quercus californica*); very slow growth.
4. Mistletoe-infested tree; very bushy and limby; some limbs almost touching ground; many branches dying.
5. Thrifty tree; open grown; 75 feet high; low crown.
6. Suppressed tree; 30 feet high; badly malformed; damaged by a falling tree; diseased; very slow growth; suppressed by golden cup oak (*Quercus chrysolepis*) and pines.
7. Mistletoe-infested tree; very bushy top; 55 feet high.
8. Very thrifty, fast-growing tree, 60 feet high, crown enclosed on two sides.

TABLE 2

Tree unions

NUMBER	DESCRIPTION OF TREES		NUMBER OF CONES GATHERED
	Staminate flowers	Pistillate flowers	
1	(1) Very thrifty	(8) Very thrifty	8
2	(1) Very thrifty	(4) Mistletoe-infested	14
3	(4) Mistletoe-infested	(7) Mistletoe-infested	11
4	(4) Mistletoe-infested	(5) Thrifty	10
5	(2) Insect infested, thrifty	(5) Thrifty	6
6	(5) Thrifty	(2) Insect-infested, thrifty	10
7	(3) Suppressed	(8) Thrifty	13
8	(3) Suppressed	(4) Mistletoe-infested	10
9	(4) Mistletoe-infested	(6) Suppressed	9
10	(8) Very thrifty	(3) Suppressed	12
11	(3) Suppressed	(3) Suppressed	8
12	(1) Very thrifty	(1) Very thrifty	13
13	(4) Mistletoe-infested	(4) Mistletoe-infested	11
14	(6) Suppressed	(3) Suppressed	21
15	(5) Thrifty	(5) Thrifty	9

For unions 11, 12, and 13, pollen was collected from different parts of the tree and mixed before fertilizing.

For unions 12 and 15, pollen was collected from nearest flowers on the same branch.

were handled alike. From the seed data which were gathered, the accompanying tables were prepared:

From the germination secured in the nursery tables 3 to 5 were made, the data being the percentage of germination at

TABLE 3

Effect of fertilization on the value of the seed

UNION	NUMBER OF SEEDS PER POUND	GERMINATION PERCENTAGE	REAL VALUE OF SEED PER POUND	HEIGHT OF 1-YEAR OLD SEEDLINGS
1	2180	59.5	1300	3.1
2	3725	34.3	1267	2.5
3	4320	24.1	1041	2.4
4	2400	38.2	917	2.7
5	2372	50.2	1191	2.9
6	0	0.0	0	
7	2142	54.2	1160	3.0
8	4062	25.1	1009	2.1
9	4233	21.4	905	2.3
10	3850	26.5	990	1.8
11	4365	19.3	742	2.1
12	2434	46.5	1073	3.0
13	3910	21.8	852	2.3
14	4128	20.7	854	1.8
15	2337	48.0	1122	2.7

TABLE 4

Rate of germination percentage by decades. Tree classes based on the source of the pistillate flowers

DAYS	THRIFTY	MISTLETOE	SUPPRESSED
20	0.0	0.0	0.0
30	0.0	0.0	0.2
40	2.5	1.5	1.3
50	7.0	3.5	2.8
60	21.5	13.5	10.5
70	48.5	27.0	19.8
80	79.0	53.5	41.3
90	91.0	71.0	56.8
100	94.5	87.0	76.5
110	100.0	93.3	82.0
120		97.5	89.8
130		98.0	93.0
150		99.5	100.0
Number of tests	6	4	4
Average germination percentage	49.4	26.3	22.0
Real value of seed	1127	1042	873

ten-day intervals divided by the final germination percentage, or the rate of germination by ten-day periods.

TABLE 5

Rate of germination percentage by decades. Tree classes based on source of the pollen

DAYS	THRIFTY	MISTLETOE	SUPPRESSED
20	0.0	0.0	0.0
30	0.0	0.5	0.0
40	3.6	2.8	3.0
50	6.2	7.5	5.8
60	19.4	20.4	17.0
70	46.5	38.3	27.8
80	66.2	73.3	65.0
90	82.8	90.5	71.2
100	93.2	97.8	81.8
110	99.0	99.5	86.5
120	99.5	100.0	94.0
130	100.0		99.0
150			99.5
Number of tests	6	4	4
Average germination percentage	44.2	26.4	29.8
Real value of seed	1141	929	941

TABLE 6

Thrifty trees

SOURCE OF UNION	PISTILLATE				STAMINATE			
	Seeds per pound	Germination percentage	Real value	Height of seedlings	Seeds per pound	Germination percentage	Real value	Height of seedlings
Thrifty	2661	51.1	1171	2.9	2661	51.1	1171	2.9
Suppressed	2142	54.2	1160	3.0	3850	26.5	990	1.9
Mistletoe	2400	38.2	917	2.7	3725	34.3	1267	2.5
Average	2401	47.8	1083	2.9	3412	37.3	1143	3.4

The data from the preceding tables are summarized in tables 6 to 9, which are based on the flowers.

The effect of self-fertilization and that of cross-fertilization is shown in table 9.

TABLE 7

Suppressed trees

SOURCE OF UNION	PISTILLATE				STAMINATE			
	Seeds per pound	Germination percentage	Real value	Height of seedlings	Seeds per pound	Germination percentage	Real value	Height of seedlings
Thrifty	3850	26.5	990	1.8	2142	54.2	1160	3.0
Suppressed	4246	20.0	789	1.9	4246	20.0	798	1.9
Mistletoe	4233	21.4	905	2.3	4062	25.1	1009	2.1
Average	4160	22.6	897	2.0	3483	33.1	989	3.3

TABLE 8

Mistletoe trees

SOURCE OF UNION	PISTILLATE				STAMINATE			
	Seeds per pound	Germination percentage	Real value	Height of seedlings	Seeds per pound	Germination percentage	Real value	Height of seedlings
Thrifty	3725	34.3	1267	2.5	2400	38.2	917	2.7
Suppressed	4962	25.1	1009	2.1	4233	21.4	905	2.3
Mistletoe	4115	22.9	947	2.3	4115	22.9	947	2.3
Average	3967	27.4	1074	2.3	3583	27.5	923	2.4

TABLE 9

Effect of fertilization

CHARACTER OF TREE	CROSS-FERTILIZED				SELF-FERTILIZED			
	Seeds per pound	Germination percentage	Real value	Height of seedlings	Seeds per pound	Germination percentage	Real value	Height of seedlings
Thrifty	2276	54.8	1246	3.0	2385	47.3	1098	2.9
Suppressed	4128	20.7	854	1.8	4365	19.3	742	2.1
Mistletoe	4320	24.1	1041	2.4	3910	21.8	852	2.3
Average	3575	33.2	1047	2.4	3553	29.5	897	2.4

RESULTS

While it is admitted that, because of the few trees, the small number of cones, and the small amount of seed involved, some decidedly conflicting results have been secured, still many of

the data here given show that there is a close relationship between the union which produces the seed and the value of the seed for nursery practice.

In general, the cones from the thrifty trees furnished the larger and heavier seed no matter what tree furnished the pollen. The seed, in addition, had a higher germination percentage, a higher rate of germination, and possibly a higher real value to the pound, and produced taller, heavier, and stronger seedlings. Cones fertilized by the pollen from thrifty trees also had the same relations.

Trees affected with mistletoe had half as many more seed to the pound as were found in the cones on thrifty trees, but the germination was 20% lower and the seedlings were not as vigorous, though the real value of the seed was about the same.

The suppressed, malformed, and diseased trees gave the largest number of seed to the pound and this seed had the lowest germination percentage, were the lowest in real value, and produced the smallest trees in the nursery.

It would appear that pollen from thrifty trees transmit some of the parent's characteristics to the seed which it fertilizes, for the seed, the germination percentage, and the real value, and the seedling growth are larger when the cones on poorer trees are fertilized with it. An apparent contradiction is shown when pollen from poorer trees fertilizes the cones of thrifty trees, but this difference is probably due to the greater strength of the pistillate flowers. Polllen from insect-infested trees apparently has no effect on the seed produced, but the effect on the pistillate flowers of the infested tree is not known from these experiments.

Cross-fertilization is to be desired because it produces larger-sized seed, greater germination powers, higher real value to the pound, and better growth in the seedling stage. This is apparently true, no matter whether applied to the suppressed or infested trees or applied to the best trees in the stand.

APPLICATION IN FORESTRY

These results have a definite and immediate bearing on field work. While it may be that the results are not so accurate that one can say definitely what would happen under a definite set of conditions, there are indications which are of great import in timber sale work, and of great import in our reforestation problems.

It appears that the heaviest seed comes from the best trees. Seed should, therefore, be collected from the thriftiest trees, and trees that are located in stands containing much mistletoe or many suppressed trees should be avoided, for the pollen transmits some of the characteristics of the parent to the seed.

Seed should not be collected from the poorer trees and infested trees because of the lower value of the seed and the deterioration that takes place in the quality of nursery stock. This point should be impressed more that it has been on those collecting tree seed, for three different collections of seed by Forest Rangers on the Angeles Forest were made from the poorer trees because of the greater ease of collection. This can only be detrimental to the vigor and growth of the forest grown from such seed.

While there is relatively little difference in the self-fertilized and cross-fertilized seed, there is enough to show that in any given region the seed should be collected from that locality which has strong winds at the time of flowering so that cross-fertilization may be secured so far as possible.

These results appear to show that in timber-sale practice only thrifty seed trees should be left, and all diseased and suppressed trees should be removed in order to secure in the future the best possible forest.

BOOKS AND CURRENT LITERATURE

Vegetation of Cape Breton.—The publication of this thoroughgoing investigation of the vegetation of northern Nova Scotia[1] is of interest not only because of the very large contribution that it makes to our knowledge of the plant associations of eastern North America, but also because it presents the results of a new experiment in the analysis and description of vegetation in general. The scheme of classification used was published in The Plant World two years ago.[2] At the time it seemed to the reviewer that the scheme was not as completely genetic as some others, but the present paper shows that it certainly makes possible a clear presentation of the development of the vegetation of a very complex region.

Nichols recognizes two "Climatic Formations" contributing to the vegetation of Cape Breton. The Northeastern Evergreen Forest Formation dominates the interior plateau and reaches its climax in the forests of balsam fir, white and black spruce and paper birch. One interesting edaphic modification of formations is the complex known as the "barrens." These occur on better grained uplands of the plateau and develop from sedge-grass heath to dwarf shrub and spruce heath, or to "krumholz," or scrub forest approaching the climatic type in composition. In the poorer drained areas the black spruce and alder predominate. The successions in ponds and lakes from aquatics to flat bogs are given together with an excellent summary of the origin, development and distribution of the raised bogs.

The lowlands are dominated by the Deciduous Forest Formation, with varying additions from the Evergreen Forest. The dominant trees in the climax association are the beech, sugar maple, yellow birch, balsam fir, hemlock and white pine. The Xerarch Series of associations includes association complexes beginning on rock outcrops glacial drift, talus, rack ravines, headlands, sea beaches and dunes. The Hydrarch Series of associations includes those of well drained and poorly drained lakes, swamps and stream margins; also those of salt and brackish

[1] Nichols, G. E. The Vegetation of Northern Cape Breton Island, Nova Scotia. Trans. Conn. Acad. Arts and Sci. **22**: 249–467. June, 1918.

[2] Nichols, G. E. Plant World. **20**: 305–319, 341–353. 1917.

lakes and marshes. This list is sufficient evidence of the complexity of the vegetation and the space of this review is quite inadequate to depict even the important details of the paper.

This paper should be read by all students of vegetation, and is to be commended for its clearness, the evident accuracy of the plant lists (including bryophytes and lichens), and the admirable discussion of climatic and edaphic conditions.—E. N. Transeau.

Physiology of the Mangrove.—The results of two summers of laboratory and field work on the red mangrove (*Rhizophora mangle*) have been published by Dr. H. H. M. Bowman of Heidelberg University, Tiffin, Ohio.[1] The work was done in Florida under the auspices of the Department of Marine Biology of the Carnegie Institution. The morphological and histological characteristics of stem, root, leaf and flower are described in detail, and the copious literature relating to this tree is reviewed in connection with each topic. The most original features of Bowman's work have to do with the transpiration of seedlings and the biochemistry of the hypocotyl.

The seedlings used for transpiration work were placed in water, in wet sand or in mud, the water being changed daily. The readings were made by means of cobalt chloride paper, dried in a desiccator and applied with an appropriate clip. No temperature readings were taken, although of great importance in calibrating results by this method, and the author made no attempt to render his results comparable with those for other plants by availing himself of the method of standardizing the paper to a water surface, as described by Livingston in 1913.[2] Seedlings were placed in rain water, in five mixtures of rain and sea water—with increasing percentages of the latter—and in pure sea water. The times required for the same color change in the cobalt chloride paper ranged from 1.6 minutes in rain water, through progressively increasing periods for the mixtures to 4.1 minutes for sea water, indicating that transpiration is over two and a half times as great in fresh water as in sea water. Determinations were made in sun and in shade, as well as in different substrata, but as separate results for the various series are not given the question arises as to why they were made. By use of the same method the transpiration through the lenticels of the crop

[1] Bowman, H. H. M. Ecology and physiology of the red mangrove. Proc. Amer. Phil. Soc. **56**: 589–672, pls. 4–9, 1917.

[2] Livingston, B. E. The resistance offered by leaves to transpirational water loss. The Plant World **16**: 1–35, 1913.

roots was measured in trees growing in fresh and in salt water indicating a more rapid rate in the former case.

Biochemical work was done to test the relation between the amounts of tannic acid and dextrose in the hypocotyl of seedlings at different stages of growth after leaving the parent tree. No definite decrease of tannin was discovered with the increasing amounts of dextrose, and no evidence of the presence of tannase was secured.

The field work carried out established the fact that the mangrove reaches its optimum development in sea water, in spite of its facultative behavior with respect to the salinity of its substratum.—Forrest Shreve.

NOTES AND COMMENT

The utilization of the national forests as grazing grounds has assumed an importance which is very great even in comparison with the primary purpose of these forests. The necessities of the last two years have made it desirable to stock the areas under government control as heavily as possible without endangering their future value. The methods by which the ranges are controlled, and the complex problem of utilizing the natural crop of forage without destroying its ability to recover, have received extended treatment by James T. Jardine and Mark Anderson in a recent bulletin of the Agricultural Department (No. 790).

The deleterious effects of overgrazing have been avoided by a careful regulation of the number of cattle or sheep allowed to graze on a given area, and by a careful fixing of the periods during which the range is utilized, especially with respect to keeping animals off in the early spring. The careful locating of salting places has been found to result in a better distribution of the stock over large areas, and has resulted, in some cases, in making it possible to increase the number of cattle by 25% in a four year period.

All of the methods by which overgrazing is detected, and by which the capacity of the range is estimated and its condition determined from time to time, afford one of the most noteworthy cases in which a valuable practical application has been made of some of the findings of plant ecology. Little is said by Jardine and Anderson about the effects of grazing on forest reproduction, a matter which is quite as important as the perpetuation of the range itself, and is well known to be receiving its due share of attention.

Grape growing is the subject of a new Rural Manual issued by the Macmillan Company under the authorship of Professor U. P. Hedrick of the Experiment Station at Geneva, New York. The book describes the propagation, pruning, training and diseases of the grape, the management of vineyards, the methods of making grape juice and raisins, and some historically interesting matter relative to the making of wines. The leading American varieties of grapes are described and illustrated.

The most interesting general feature of the book is a description of the grape growing regions of the United States and their climatic features. The narrowly localized character of the grape industry in New York, Ohio and California is shown to be due to topographic features which assure a long growing season and a sunny summer.

E. Blatter and F. Hallberg are publishing in the Journal of the Bombay Natural History Society (Vol. 26) a Flora of the Indian Desert. Their annotated list of species is given additional importance by the insertion of numerous illustrations of vegetation in the little known and extremely arid states of Jodhpur and Jaisalmer, in the western Rajputana. Extended areas of moving sand are extremely poor in vegetation. The prevailing open stand of low bushes is chiefly made up of species of *Leptadenia*, *Prosopis*, *Acacia*, and *Aerna*. In moist situations the characteristic trees are *Salvadora*, *Gymnosporia*, *Capparis* and *Zizyphus*.

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SUNLIGHT AND ITS MEASUREMENT

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The term "sunlight" applies strictly only to that portion of the sun's radiation that is capable of producing sensations of light in man. Although it cannot be said that only this portion affects plants it undoubtedly presents a greater share of today's botanical problems than any other portion of the sun's spectrum. For this reason the peculiar difficulties presented by the ultra-violet and infra-red portions are largely omitted in the following discussion. The first part of this paper is intended as a brief, non-technical statement of our present knowledge concerning the distribution and the amount of energy in the incoming radiation from the sun. The second part only outlines the complex subject of the measurement of the sun's radiation but it is hoped that the notes on some of the necessary precautions of manipulation and interpretation attending the use of the various methods will be helpful. From the standpoint of the expert in these fields the treatment of some methods is unnecessarily detailed and that of others too fragmentary to serve as a guide for beginners. Since it is out of the question to prepare such a guide in the form of a journal article the author has been guided in his selection by two considerations: the state of knowledge of many graduate students in biology regarding the interpretation of data secured by methods that plant physiologists and ecologists have used; the author's intention to direct attention to some of the advantages, disadvantages and peculiarities of other methods in the hope that the beginner will be induced to become really familiar with a method before publishing data secured by its use and will not adhere to the belief that if an instrument is well built the user need only consider the scale-readings. A short literature list is added to indicate the locations of some of the more thorough discussions of the important points.

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I. SOLAR RADIATION

As botanists we are but little concerned with the origin and maintenance of the sun's radiation as a subject for investigation. Unless, however, the fundamentals of the subject are grasped our reasoning and measurements are quite likely to lead to wholly erroneous botanical generalizations; a misfortune that is realized in practically all our texts in plant physiology.

Radiation is produced by vibrations of small particles, atoms or electrons, called radiators for brevity. An increase in temperature (absorption of energy) increases the rates of vibrations of these radiators, increasing their *output* of energy and the *frequency* with which they vibrate.[1] Thus the *intensity* of radiation is increased and the *wave length* shortened. Several laws, of which Wien's, Stefan's and Planck's are the most general, connect the temperatures of certain types of radiating bodies with measurable features of their spectra. From these laws[2] the temperature of a Kirchoff radiator (so-called "black body," *i.e.*, a uniformly heated enclosure radiating by temperature only) that would approximately reproduce the sun's spectrum has been calculated. Such a calculation leads to a temperature of about 6000° absolute, which is often erroneously stated to be approximately equivalent to the sun's actual temperature.

Since we have little accurate knowledge concerning the original character of the radiation in the sun's interior (this original spectrum is, of course, considerably altered in passing through the cooler outer layers of the sun)[3] and since chemical

[1] See: Preston, T., The theory of heat. 2nd ed. New York, 1894.

Idem. The theory of light. New York, 1895.

Wood, R. W., Physical Optics. New York, 1905.

Drude, P., Lehrbuch der Optik. 2te Aufl. Leipzig, 1906. Or any other good text dealing with radiation.

[2] See, for example, Preston's Heat (cited in note 1). A good account is given by Lewis, W. C. McC., A system of physical chemistry. Vol. 2, pp. 359–542. New York, 1916.

[3] A brief discussion is given by Abbot, C. G., Ann. Astrophys. Obs. Smithsonian Inst. **3**: 12; 139; 194–202. 1913; *Idem.* The sun's energy spectrum and temperature. Astrophys. J. **34**: 197–208. 1911; *Idem.* The sun. New York, 1911.

action probably plays a considerable part in producing short-wave radiation without necessitating temperature increases of the magnitudes required by the radiation laws mentioned above, it seems clear that the actual temperature of the sun may be far above or far below the figure given. However, it also seems clear that changes—even local—in the sun's temperature or translocations of chemically active material, both of which occur, may alter the sun's spectrum both in total energy and in distribution of energy. The terrestrial significance of these solar changes cannot be stated as yet but it appears[4] that there are two general processes operating; long term variations (measured in months or years) in the effective temperature of the sun, altering the total energy and its spectral distribution; short term changes (perhaps measurable in days) in transparency of the outer envelopes of the sun which probably affect chiefly the shorter waves.

Since the intensity of radiation received at the earth from any given luminous point on the sun varies inversely as the square of the distance intervening it follows that the energy incident upon a given area of the earth's surface will vary with the time of year (*i.e.*, with changes in the earth's distance from the sun) from this cause alone to produce a maximum difference of about five per cent. Accordingly, astro-physicists alter their radiation figures to those that would be correct if the earth's orbit was a circle with radius equal to the average distance from the sun to the earth's present orbit. Since the total energy content of the sun's spectrum must vary with changes in the sun, the "solar constant" (the number of 15° calories received as radiation from the sun upon an area of 1 sq. cm. in one minute at equatorial sea level with the sun 90° above all points on the horizon and the earth at its mean orbital distance from the sun if all the earth's atmosphere were removed) should vary likewise, as is, indeed, the case.[4] The *mean* solar

[4] Abbot, C. G., F. E. Fowle and L. B. Aldrich, On the distribution of radiation over the sun's disk and new evidences of solar variability. Smithsonian Misc. Coll. **66**: No. 5. 1916.

constant[5] of radiation is at present taken to be 1.93 calories per square centimeter per minute, but the variations even from day to day are distinctly noticeable. For example[4] the solar constant for August 19, 1913, is given as 1.86 calories, whereas the next day it appeared to be 1.99 calories.

Before passing to a discussion of the distribution of energy in the sun's spectrum it seems necessary to consider the distinction between prismatic and normal spectra, for the discussion and graphs to follow are based upon the latter.[6]

Imagine a beam of light emitted by radiators of such numbers and kinds that only waves between, let us say, 0.4μ and 0.8μ are produced and that the intensity of radiation is the same for all wave lengths, thus rendering the character of the radiation as simple as possible. Imagine this beam to be passed through an instrument that deflects the radiation of each wave length along a line at right angles to their common path, the degree of deflection being proportional to the wave length, and that the instrument does nothing else whatsoever to the radiation. Suppose further that this beam is projected upon a screen to form a colored spectrum, which will be visible as a band. The total energy incident upon the screen in unit time will thus be exactly equal to the energy that would have been transmitted to the screen in the same time if the instrument had done nothing whatever to the beam, *i.e.*, the beam has lost no energy through deflection of the waves. Since the deflection is proportional to the wave length and the energy transmitted in the wave lengths were originally all equal it follows that equal areas in the illuminated portion of the screen receive equal amounts of energy in unit time. In other words, if the positions of the wave lengths were marked on the screen as abscissas, and corresponding ordinates were erected whose lengths are proportional to the intensities of radiation on unit screen areas at several points, a line joining their tops would be straight and parallel to the base. Such a spectrum, with dispersions proportional to the wave

[5] Abbot, C. G., Pyrheliometry and solar radiation. Science N. S. **47**: 609–610. 1918.

[4] Baly, E. C. C., Spectroscopy. New York, 1905.

Kayser, H., Handbuch der Spectroscopie. Bd. 1–6. Leipzig, 1900.

lengths, is called a normal spectrum and a graph of the particular one just considered to show its energy distribution is exhibited in figure 1.

If, however, the beam were passed through a prism the dispersions would not be in the same proportion for all wave lengths with the result that the radiation of the longer wave lengths would be more concentrated toward one end of the spectrum and that of the short wave portion would be spread over a greater area than in a normal spectrum of the same beam. The

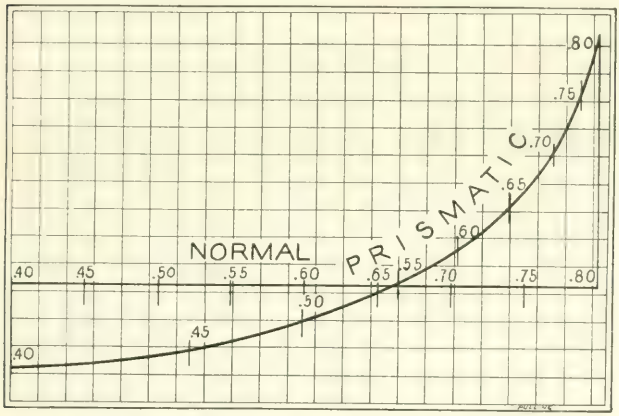

Fig. 1. Graphs of the distribution of energy in an hypothetical beam of light when obtained from prismatic and normal spectra that cover the same area on the screen. Ordinates represent intensities in arbitrary units; abscissas, representing wave lengths, are noted on the curves.

graph of a spectrum of the beam of light described above is shown as the prismatic spectrum line of figure 1. The *apparently* higher energy content of the long red rays relative to the shorter blue ones is now seen to be solely due to the fact that the latter cover approximately nine times as much surface on the hypothetical screen as the former. If the energy content at each wave

length could be measured separately there would be no difference between the normal and prismatic energy spectra for the energy is not redistributed among waves of different lengths by the prism. But since all energy measurements are made by exposing small areas to the incident radiation, the crowding of the longer waves closer together than the others gives data that must be corrected for this crowding, the amount of correction depending upon the characteristics of the actual prism used. Of course, if the energy content of the original beam had not been equally distributed among the waves of different lengths the normal energy spectrum graph would not be parallel to the base as in the case above, although the ordinates would measure the relative distribution in the original beam correctly.

It is at once obvious that no idea of the distribution of energy in a beam of light can be *directly* drawn from a prismatic energy graph, or from measurements upon a prismatic spectrum. If, however, the abscissas of the graph are drawn accurately proportional on a sufficiently large scale to the dispersions actually encountered (or better still if the dispersions themselves are given), coefficients[7] may be obtained by which the prismatic graph can be converted into a graph of a *normal* spectrum in which equal numbers of wave lengths cover equal areas, *i.e.*, the dispersions are all in the same ratio to their corresponding wave lengths. The proper coefficients multiplied into the values of the prismatic energy ordinates of figure 1 result in the graph of a normal spectrum of equal *total* energy (equal areas between the curves and the same base line). The values of these coefficients for any range of wave lengths will depend upon the shape and nature of the prism[8] so that a graph of the intensities plotted on "a prismatic scale" affords no clue to the actual distribution of energy in the original beam—the

[7] These may be obtained by plotting the wave lengths as abscissas against the distances of the positions of these wave lengths from a fixed point on the base line of the actual spectrum chart. The trigonometrical tangents of the angles formed by the intersections of tangents drawn from points on the curve to the base line of the chart are the coefficients desired.

[8] The dispersion data used in the construction of figure 1 were obtained from measurements with an actual 60° prism.

actual prismatic scale (*i.e.*, the dispersions encountered) must be given. It is to be hoped that the uninterpretable prismatic spectra that are usually presented in biological exposition will be abandoned and that normal energy spectra will be published.

Because selective deductions of energy occur in the outer envelopes of the sun, thereby producing the Frauenhofer lines, it is obvious that measurements of the energy distribution in the spectrum will not yield a smooth curve. Instead, the graph will exhibit many irregularities and where the Frauenhofer lines are very close together the intensity will be so reduced that the curve will exhibit great depressions, as is the case in the short-wave portion.

A smoothed graph prepared from averages of a large number of observations is, however, useful in exhibiting the general form of the energy distribution curve without the distractions consequent upon the simultaneous presentation of the irregularities caused by absorption in the outer envelopes of the sun. Such a curve[9] is presented in figure 2, drawn to normal scale. It is evident that the maximum intensity falls very nearly at $\lambda = 0.47\mu$, which is very close to the G line and about where blue becomes changed to indigo. Since the "mean solar constant" is given as 1.93 15°−calories, calculations from a measurement of the area enclosed between the curve and its base show that each of the small rectangles in the figure corresponds under the conditions for which the solar constant is defined to approximately 0.0294 calories. From this value and measurements of the proper ordinates in the graph, the energy values between chosen wave lengths may be rather readily estimated. As has been noted this is a curve of averages, the actual curve obtained on any given day differs from it to some extent both in total area enclosed and in form.

The "solar constant"[10] fluctuates irregularly, values of from

[9] Abbot, C. G., The sun's energy spectrum and temperature. Astrophys. J. **34**: 197–208. 1911.

[10] The term "solar constant" has obviously proved to be unfortunate and before a larger volume of literature has further sanctioned its use a more accurately descriptive term should be substituted.

about 1.8 to about 2.0 have been recorded almost every year. "No regular periodicity seems to appear, but the values often range from low to high and return within seven to ten days. The range frequently reaches 5%."[11] Although the averages for the summers during which measurements were made agree very closely with each other, as table 1 indicates, the total range of fluctuation (from about 1.81 to about 2.04) is approximately 12% of the "mean solar constant" given above.

TABLE 1

Solar constant values. Summary: 1902–1912. Ann. Astrophys. Obs. Smithsonian Inst., table 44, p. 134, vol. 3, 1913

STATION	DATE	NUMBER OF OBSERVATIONS	MEAN VALUE
Washington	1902–1907	37	1.968
Mount Wilson	1905, June–October	45	1.956
	1906, May–October	61	1.942
	1908, May–November	114	1.936
	1909, June–October	95	1.916
	1910, May–November	113	1.921
	1911, June–November	109	1.923
	1912, June–August	36	1.945
Mount Whitney	1909–1910	4	1.895*
Bassour	1911, September–November	43	1.913
	1912, June–August	39	1.943

* This value becomes 1.923 if the results are changed in a manner that the authors believe advisable.

Regarding the changes in the form of the solar energy curve little can be said at present. The evidence seems to point to a variability in the shorter waves that is proportionally greater than for longer waves.[12] This may be seen by comparing the ordinates of figure 2 with those of figure 4, the maximum in the former case falling at wave length 0.47μ and in the latter case at about 0.40μ.

[11] Ann. Astrophys. Obs. Smithsonian Inst. **3**: 119. 1913.

[12] Ann Astrophys. Obs. Smithsonian. Inst. **3**: 131–133. 1918.

Turning from the extra-terrestrial influences upon the sun's radiation we may consider the much more profound alterations induced within the earth's atmosphere. The absorption of certain wave lengths to a greater degree than others renders some non-luminous objects colored, while others that absorb only those waves lying outside the visible spectrum remain colorless to our eyes although they absorb energy. In this way the constitutents of the atmosphere produce lines and

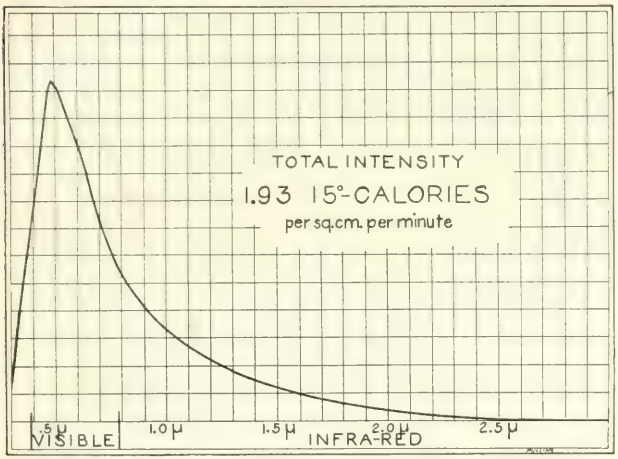

Fig. 2. Smoothed graph of the energy distribution in a normal spectrum of the sun's radiation outside the atmosphere.

bands in the sun's spectrum for the same reason and in the same way that the Frauenhofer lines are produced. Rowland[13] gives about 440 atmospheric lines, exclusive of those caused by

[13] Rowland, H. A., A preliminary table of solar spectrum wave lengths. Astrophys. J. **1**: 29-46; 131-145; 222-231; 295-304; 377-392. 1895; **2**: 45-54; 109-118; 188-197; 306-315; 360-369. 1895; **3**: 141-146; 201-206; 356-373. 1896; **4**: 106-115; 278-287. 1896; **5**: 11-25; 109-118; 181-193. 1897. Corrections and additions to Professor H. A. Rowland's table of solar spectrum wave lengths. Astrophys. J. **6**: 384-392. 1897.

water vapor, between wave lengths 0.47μ and 0.76μ; the shortest wave length unquestionably absorbed in our atmosphere in this region is given at 0.586μ and is a water vapor band. In addition to these there is probably some absorption in the ultra-violet, and a great deal of absorption in the infra-red.

The great majority of these absorption bands are so narrow that their effects are similar to those of the Frauenhofer lines. At wave lengths greater than 0.67μ, however, wide terrestrial absorption bands occur.[14] An idea of the position of these

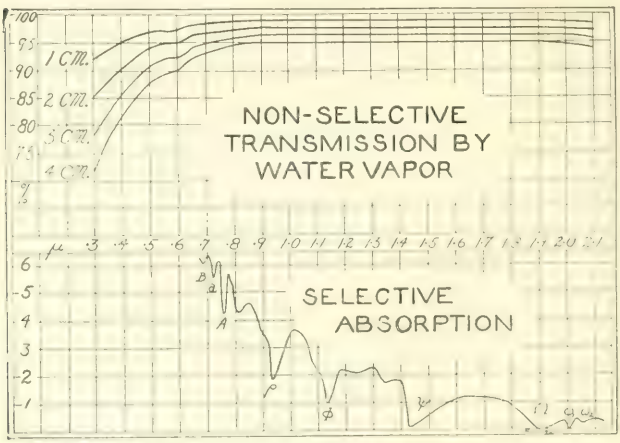

Fig. 3. Graphs of the effects of some atmospheric constituents upon solar radiation.

bands and their relative energy absorption may be gained from figure 3 which was obtained by converting a graph by Fowle[14] to normal scale. The data for the various bands in table 2 were taken from Fowle's paper. A number of fine

[14] Fowle, F. E., The transparency of aqueous vapor. Astrophys. J. **42**: 394–411. 1915.

Paschen, F., Ueber die Emission der Gase. Ann. Physik. Chem. (N. F.) **52**: 209–237. 1894.

aqueous lines between 0.535μ and 0.650μ produce a depression not shown in this graph but whose effect may be noted by the decreased transmission shown in the upper graphs of figure 3. It will, of course, be evident that the absorption in the water vapor bands will increase and decrease with changing atmospheric contents of water so that the areas of the corresponding depressions in the curve will change likewise.

The effect, of water vapor upon the incoming radiation is, of course, dependent upon the total amount of vapor through which the beam passes. This amount of vapor is usually stated as the number of centimeters of "precipitable" water, *i.e.*, the depth of water that, when evaporated into a vertical column of air of the same cross section, would produce the amount of vapor that would actually be encountered between the observing station and the limit of the atmosphere in a cylinder of the same cross section. There is, however, no simple relation by which vapor pressure determinations at the level of the observing station can be converted into equivalent values for depths of precipitable water because air currents produce unknown changes in the moisture content of the air above the level at which the determinations are made.

Empirical expressions have been formulated by Hann[15] and by Humphreys[16] to express the mean or average relation between these two quantities.[17] At elevations above sea level allowances must be made for altitude.[18]

[15] Hann, J. von, Lehrbuch der Metereologie. 3te Aufl. 224–226. Leipzig, 1915.

[16] Humphreys, W. J., The amount and vertical distribution of water vapor on clear days. Bull. Mt. Weather Obs. **4**: 121–128. 1911.

[17] If the depth of precipitable water vertically above a station at sea level is denoted by Q_0 and the prevailing vapor pressure in centimeters of mercury at the same sea level station by e_0, the usual form of the expression connecting them is $Q_0 - Ke_0$, in which K is an empirical constant. Hann found $K = 2.3$, while Humphreys takes it as 2.0 for "clear days."

[18] For a discussion of this question and a more accurate method for determining precipitable water see Fowle, F. E., The spectroscopic determination of water vapor. Astrophys. J. **35**: 149–162. 1912.

Idem ibid. Ann. Astrophys. Obs. Smithsonian Inst. **3**: 171–181. 1913. *Ibid.* The determination of the aqueous vapor above Mount Wilson. Astrophys. J. **37**: 359–372. 1913.

Idem. ibid. Ann. Astrophys. Obs. Smithsonian Inst. **3**: 182–193. 1913.

For convenience in interpreting figure 3, vapor pressures corresponding to 1, 2, 3 and 4 cm. of precipitable water at sea level and at 1780 meters are given in table 3, using both Hann's and Humphreys' constants. Data showing the effects of various amounts of water in the atmosphere above two different stations in selectively absorbing radiation are given in table 5.

The oxygen bands, A and B and the two small bands, ω_1 and ω_2, are practically constant in area at any given station and

TABLE 2

Atmospheric absorption bands

SYMBOL	WAVE LENGTH OF MAXIMUM ABSORPTION	ABSORBING SUBSTANCE	SYMBOL	WAVE LENGTH OF MAXIMUM ABSORPTION	ABSORBING SUBSTANCE
B	0.69 μ	Oxygen	φ	1.13 μ	Water vapor
a	0.72 μ	Water vapor	ψ	1.42 μ	Water vapor
A	0.76 μ	Oxygen	Ω	1.89 μ	Water vapor
—	0.81 μ	Water vapor	ω_1	2.01 μ	Unknown
$\rho\sigma\tau$	0.93 μ		ω_2	2.05 μ	Unknown

TABLE 3

Relation of surface vapor pressure to amount of precipitable water

PRECIPITABLE WATER	VAPOR PRESSURE IN MILLIMETERS OF MERCURY			
	At sea level		At 1780 meters	
cm.	Hann	Humphreys	Hann	Humphreys
1	4.4	5.0	5.3	6.3
2	8.7	10.0	10.5	11.8
3	13.0	15.0	15.8	17.6
4	17.4	20.0	21.0	23.6

data showing the extent of their influences are also given in table 5.

There are two carbon dioxide bands extending from 3.6μ to 5.4μ and from 13.0μ to 16.0μ[19] but an inspection of figure 2 evidences that, because the positions of these bands are in re-

[19] Ångstrom, K., Ueber die Bedeutung des Wasserdampfes und der Kohlensäure bei der Absorption der Erdatmosphäre. Ann. Physik. (4) **3**: 720–732. 1900.
Idem. Ueber die Abhängigkeit der Absorption der Gase, besonders der Kohlensäure, von der Dichte. Ann. Physik (4) **6**: 163–173. 1901.

gions of such low energy content, the effect of carbon dioxide in diminishing the incoming radiation to the earth is of no importance.

Nitrogen and hydrogen apparently have no bands.

Another source of possible deduction of energy lies in the absorption of energy in chemical reactions in the atmosphere. If such reactions do occur they appear to be limited to the ultra-violet portion of the spectrum where the energy is removed from the solar beam by transformations of ozone and oxygen.[20] It is very difficult to arrive at a satisfactory notion of the

TABLE 4

Ratios of transmitted to scattered radiation

	FRAUENHOFER LINE			
	C	D	b_1	F
Ratio calculated by Rayleigh	25	40	63	80
Ratio observed on Mount Wilson	25	35	60	77

magnitude of this effect since it occurs probably only in the outermost portions of the gaseous envelope. The ultra-violet radiation seems to be extremely effective in producing nucleation of the air.[21] Saltmarsh for example, stating that nuclei were

[20] Kron, E., Uber die Extinction des Lichtes in der Erdatmosphäre für das Ultraviolet. Ann. Physik **45**: 377–398. 1915.

[21] Arrhenius, S., Ueber den Einfluss der Sonnenstrahlung auf die elektrischen Erscheinungen in der Erdatmosphäre. Meteor. Zeit. **5**: 297–304. 1888.

Elster, J., and H. Geitel, Beobachtungen des atmosphärischen Potentialgefälles und der ultravioletten Sonnenstrahlung. Sitzungsber. Math.-Nat. Cl. Ksl. Akad. Wien, **101**. Abt. 2A: 703–856. 1892.

Wilson, C. T. R., On the condensation nuclei produced in gases by the action of Röntgen rays, Uranium rays, ultra-violet light, and other agents. Phil. Trans. Roy. Soc. **192**: 403–453. 1899.

Barus, C., The nucleation of the uncontaminated atmosphere. Carnegie Inst. Wash. Pub. 40. 1906.

Idem. Über die Verteilung der Kondensationskerne in staubfrier Luft, und über ihre Beobachtungsmethoden. Ann. Physik. (4) **24**: 225–242. 1907.

Idem. Condensation of vapor as induced by nuclei and ions. Carnegie Inst. Wash. Pub. 62. 1907.

Idem. Condensation of vapor as induced by nuclei and ions. Carnegie Inst. Wash. Pub. 96 (Part 2). 1910.

Saltmarsh, Maud, Experiments on condensation nuclei. Proc. Phys. Soc. London **27**: 357–370. 1915.

TABLE 5

Losses from the solar beam in the earth's atmosphere

PRECIPITABLE WATER VAPOR	SUN'S APPROXIMATE ALTITUDE											
	90°		31°		19°28′		14°29′		11°32′		8°13′	
	Gm. cal lost	Per cent lost	Gm. cal lost	Per cent lost	Gm. cal lost	Per cent lost	Gm. cal lost	Per cent lost	Gm. cal lost	Per cent lost	Gm. cal lost	Per cent lost
Mt. Wilson, alt., 1780 meters; barometer, 62.3 cm. Total incoming radiation 1.93 gm. cal.												
0.00 cm.												
Air scattered	0.15	7.8	0.28	14.5	0.38	19.7	0.47	24.4	0.54	28.0	0.66	34.2
Air absorbed	0.01	0.5	0.01	0.5	0.01	0.5	0.02	1.0	0.02	1.0	0.02	1.0
0.33 cm.												
H_2O scattered	0.02	1.0	0.02	1.0	0.04	2.1	0.04	2.1	0.04	2.1	0.05	2.6
H_2O absorbed	0.11	5.7	0.13	6.7	0.14	7.3	0.15	7.8	0.16	8.3	0.17	8.8
0.50 cm.												
H_2O scattered	0.03	1.6	0.03	1.6	0.06	3.1	0.06	3.1	0.07	3.6	0.08	4.1
H_2O absorbed	0.12	6.2	0.15	7.8	0.16	8.3	0.17	8.8	0.18	9.3	0.19	9.8
1.00 cm.												
H_2O scattered	0.04	2.1	0.08	4.1	0.10	5.2	0.12	6.2	0.13	6.7	0.15	7.8
H_2O absorbed	0.15	7.8	0.17	8.8	0.19	9.8	0.20	10.4	0.21	10.9	0.22	11.4
2.00 cm.												
H_2O scattered	0.09	4.7	0.13	6.7	0.19	9.8	0.21	10.9	0.25	13.0	0.28	14.5
H_2O absorbed	0.18	9.3	0.21	10.9	0.23	11.9	0.24	12.4	0.24	12.4	0.25	13.0
Total lost	0.43	22.0	0.63	33.0	0.81	42.0	0.94	49.0	1.05	54.0	1.21	63.0
Washington (dust included under water vapor), alt., 10 meters; barometer, 76.0 cm. Total incoming radiation 1.93 gm. cal.												
0.00 cm.												
Air scattered	0.18	9.3	0.33	17.1	0.44	22.8	0.53	27.5	0.61	31.6	0.73	37.8
Air absorbed	0.01	0.5	0.01	0.5	0.01	0.5	0.01	0.5	0.01	0.5	0.01	0.5
0.5 Feb. 15.												
H_2O scattered	0.08	4.1	0.15	7.8	0.21	10.9	0.26	13.5	0.30	15.5	0.37	19.2
H_2O absorbed	0.12	6.2	0.13	6.7	0.14	7.3	0.14	7.3	0.14	7.3	0.14	7.3
1.8 Oct. 4.												
H_2O scattered	0.26	13.5	0.42	21.8	0.53	27.5	0.61	31.6	0.67	34.7	0.74	38.3
H_2O absorbed	0.15	7.8	0.16	8.3	0.16	8.3	0.14	7.3	0.13	6.7	0.11	5.7
2.4 May 14												
H_2O scattered	0.38	19.7	0.56	29.0	0.67	34.7	0.71	36.8	0.78	40.4	0.83	43.0
H_2O absorbed	0.16	8.3	0.16	8.3	0.15	7.8	0.14	7.3	0.13	6.7	0.10	5.2
Total lost	0.73	38.0	1.06	55.0	1.27	66.0	1.42	74.0	1.53	79.0	1.67	86.0

produced in 50 cm. of atmospheric air. Ionization of the air removes some energy from the solar beam and appears to be of direct physiological importance.[22]

Besides the effects so far considered, which occur at rather isolated portions of the spectrum, there is another effect that is common to all radiation but varies in degree from wave length to wave length: the "scattering" of the radiation by the gases of the atmosphere to which is attributed the blue color of the sky.[23] Brücke[24] and Tyndall[25] produced artificial skies in tubes by forming clouds by gaseous chemical reactions. As the particles became larger and larger the color, at first azure blue, assumed a whitish cast indicating that the particles were so large that they reduced the light by regular reflection. Rayleigh[26] came to the conclusion that the blue color is produced

[22] Spoehr, H. A., Variations in respiratory activity in relation to sunlight. Bot. Gaz. **59:** 366–386. 1915.

[23] Nichols, E. L., Theories of the color of the sky. Phys. Rev. **26:** 497–511. 1908.

[24] Brücke, E., Ueber die Farben whelche trübe Medien in auffallenden und durchfallenden Licht zeigen. Pogg. Ann. **88:** 363–385. 1913.

[25] Tyndall, J. On the blue colour of the sky, the polarization of skylight by cloudy matter generally. Proc. Roy. Soc. London **17:** 223-233. 1868.

[26] Rayleigh (J. W. Strutt), On the light from the sky, its polarization and colour. Phil. Mag. (4) **41:** 107–120; 274–279. 1871.

Idem. On the scattering of light by small particles. Phil. Mag. (4) **41:** 447–454. 1871.

Idem. On the transmission of light through an atmosphere containing small particles in suspension and on the origin of the blue of the sky. Phil. Mag. (5) **47:** 375–384. 1899.

Burton, C. V., Scattering and regular reflection of light by gas molecules. Phil. Mag. (6) **29:** 625–636. 1915; (6) **30:** 87–105. 1915.

The somewhat extensive controversy regarding the ability of gas molecules to scatter light seems to be settled by recent experiments on the subject, see:

Strutt, R. J., Scattering of light by dust free air, with artificial reproduction of the blue sky—Preliminary note. Proc. Roy. Soc. London **94A:** 453–459. 1918.

Idem. The light scattered by gases; its polarization and intensity. Proc. Roy. Soc. London **95A:** 155–176. 1918.

Wood, R. W., The scattering of light by air molecules. Phil. Mag. (6) **36:** 272-273. 1918.

Strutt, R. J., The scattering of light by air molecules. Phil. Mag. (6) **36:** 320-321. 1918.

Larmor, J., The principle of molecular scattering of radiation. Phil. Mag. (6) **37:** 161–163. 1919.

by the molecules of the air and not by larger particles suspended in the atmosphere, and calculated that the effect of these molecules upon the light varied inversely as the fourth power of the wave length. In table 4 are given calculations which Rayleigh made for the ratios between the intensities in a direct beam of sunlight and those of skylight near some of the Frauenhofer lines, together with some of the ratios obtained by Abbot[27] on Mount Whitney.

The calculations upon which Rayleigh's figures are based assume that there is no other effective constituent of the atmosphere besides the permanent gases. This is, however, not true in any actual case for, besides dust there is always a certain amount of water vapor present. It has been found[28] that water in the atmosphere besides exerting selective absorption at certain regions of the spectrum also scatters light. This effect of atmospheric water vapor increases as the wave length decreases so that if its effect is added to the intensity of the direct beam of sunlight, the observed figures in table 4 will still more closely approximate those calculations. The decrease in the ratios at about the D line is at least partly explainable by the presence in that region of a number of fine aqueous lines located between the limits of about 0.535μ and about 0.650μ. A graph exhibiting the non-selective transmission by different depths of precipitable water is given in figure 3 and was plotted from Fowle's data. The abscissas signify wave lengths and the ordinates the percentages of the radiation transmitted in a direct beam from zenith sun. The depression near 0.60μ indicates the selective absorption in the fine lines mentioned above.

Dust in the air reduces the transmitted energy by the amount it absorbs and the amount it reflects outward into space. The particles of dust are, however, so large relative to the wave length of light that they do not scatter the radiation as molec-

[27] Ann. Astrophys. Obs. Smithsonian Inst. **2**: 156. 1908.

[28] Fowle, F. E., The non-selective transmissibility of radiation through dry and moist air. Astrophys. J. **38**: 392–406. 1913.

Idem as cited in note 14.

ular dispersions do, but reflect it by regular reflection. The sky in consequence of the presence of dust assumes a whitish tinge indicating that the light is regularly reflected from one particle to another so that although it is reduced in quantity by the time it reaches the observer the light is of much the same quality as that originally incident upon the dust particles. This, however, is not the whole story with regard to dust or particles of water, such as may be contained in clouds. There are a number of things to be taken into consideration in attempting to estimate these effects. In the first place many of the dust particles may be electrical conductors and if this is the case they would not behave with respect to light as do non-conductors (as are the permanent gases of the air) since the light is electro-magnetic in nature. Changes in surface, shape, etc., of conducting dust particles will make large changes in their optical properties.[29]

The whole question of the color of transmitted radiation through suspended particles, large with respect to the wave length of the radiation considered is complicated. If light is incident on a body that is not absolutely opaque some light is reflected at the surface, some is absorbed in the interior, some is reflected from the interior back to the surface again (again suffering some absorption) and the remainder is transmitted. The light reflected from the first surface may be of all incident wave lengths or the body may exhibit selective reflection as is the case with copper, gold, some aniline dyes, etc.[30] If the body has very little depth (as water droplets in clouds, very fine dust particles, etc.) the internally reflected light is generally negligible. Reflected light is affected not only by the internal reflections but also by the relative index of refraction of the substance with respect to that of the

[29] See, for example, Garnett, J. C. M., Colours in metal glasses and in metallic films. Phil. Trans. Roy. Soc. London **203A**: 385–420. 1904.

Idem. Colours in metal glasses, in metallic films, and in metallic solutions. Phil. Trans. Roy. Soc. London **205A**: 237–288. 1906.

[30] Wood, R. W., Physical Optics, Chap. 14; Preston, Theory of light; cited in note 1. A brief exposition will be found in Burton, E. F., The physical properties of colloidal solutions, Chap. 5. London, 1916.

medium in which it is immersed (in the case of dust, clouds, etc., this immersing medium is air), for absorbing substances have a high refractive index on the red side of the absorption band and a low refractive index on the blue side so that a spectrum of the reflected light will be brightest on the red side of the absorption band. If the small particles are, however, large with respect to the wave length of light the intensity of the reflected or scattered light increases with *increasing* wave length and in addition varies as the square of the diameter of the particles. Thus the transition from extremely small particles that scatter the light inversely as the fourth power of the wave length, to those of microscopic size affords an enormous range of possibilities.[31] This last statement concerning the influence of the size of particles and the wave length of light may be put into one algebraic expression that indicates the necessary existence of some wave length of the radiation (not necessarily in the visible spectrum) for which the scattered radiation has the greatest intensity. There is also to be taken into account, in the case of radiation that is transmitted through a body, the relative dispersions of this body and the medium in which it is immersed.[32]

From this very brief and fragmentary statement it is obvious that, from the point of view of prediction, little can be said concerning the total effect upon radiation of the atmosphere at any given time. This is not only true because our knowledge of the precise conditions make the inaccuracy of such statements inevitable, but also because of the difficulty of drawing quantitative inferences (and in the case of color, predictive statements must necessarily be quantitative) from the very complex equations that would be necessary to include all the conditions encountered. However, it may be found that the complex conditions in nature actually exhibit relatively simple indicative

[31] Mie, G., Beiträge zur Optik trüber Medien, speziell Kolloidaler Metallösungen. Ann. Physik (4) **25**: 377–445. 1908.

[32] Wood's Optics, cited in note 1.

Christiansen, C., Untersuchungen über die optischen eigenschaften von fein vertheilten Körpern. Ann. Physik **23**: 298–306. 1884.

Garnett, cited in note 29.

characters because of the laws under which the phenomena are produced, so that once we are enabled to recognize these characters we may be able to draw sufficiently accurate conclusions regarding the effects of the entire complexes.

For example, Abbot[33] found that the high volcanic dust encountered in the late summer of 1912 reduced the intensity of the direct beam of the sun by as much as 20%, and yet the effect on the various portions of the spectrum was very nearly the same for all wave lengths in the visible spectrum. It does not follow that this will be true for all dust clouds. In the article referred to just above, Abbot quotes Arago to the effect that in the year 1831 the volcanic eruptions reduced the intensity of the light very greatly and the sun was exhibited to the unaided eye as azure, greenish or emerald. The same diversity in the character of the radiation in a cloudy sky may be observed frequently, some clouds appearing reddish while neighboring ones are perhaps deep blue.

Finally it may be noted that the upper surfaces of fog clouds, as distinguished from the high cirrus clouds, apparently reflect about 65% of the radiation incident upon them so that by reflection alone such clouds reduce the intensity of the radiation reaching the earth by about 65%.[34]

The discussion may be concluded with a statement of the average (so far as experience goes) effects of the conditions that have been mentioned.

Losses from incoming solar energy occur in seven ways:

(1) General scattering by the permanent gases of the atmosphere.

(2) General scattering by water vapor.

(3) Selective (banded) absorption by the permanent gases.

(4) Selective (banded) absorption by water vapor.

(5) Absorption and reflection by clouds.

(6) Absorption and reflection by dust.

(7) Absorption in chemical reactions.

It is at once evident that the effect of each of these conditions

[33] Ann. Astrophys. Obs. Smithsonian Inst. **3**: 216. 1913.

[34] Ann. Astrophys. Obs. Smithsonian Inst. **2**: 136–145. 1908.

increases with the amount of the effective substance between the observer and the sun, that is to say, the effect increases not only with the increase in concentration of effective material per unit distance along the path of the light beam, but also with the total distance traversed by the light beam through the atmosphere with any given concentration of effective material.

The general scattering and selective absorption due to the gas molecules will increase as the density of the atmosphere increases and with a longer path of the light rays through the atmosphere. It will thus vary with the altitude, with barometric pressure at the same altitude, and with the time of day and the time of year at the same altitude and with the same barometric pressure.

The general scattering and selective absorption produced by water vapor will vary with the changes in the total amount of water vapor in the atmosphere between the earth and the sun, with the time of day and the time of year.

The dust effects will vary with the composition, shape, size, etc., of the dust particles and the position of the sun with reference to them and to the observer.

So little is known of the effects of clouds that a summary of their possible effects may be omitted.

The graphs in figure 4 illustrating the total energy reaching the earth in the sun's radiation are self-explanatory and may serve as an integrated summary of that portion of the foregoing discussion that considers the effects of the altitude of the observer, the sun's altitude above the horizon, the general scattering by the permanent gases and by water vapor, the irregular contour of the sun's energy curve outside the atmosphere and the constant shifting of the maximum intensity toward the longer waves as the sun's altitude decreases. Table 5 indicates the manner in which these losses are distributed between the permanent gases of the atmosphere and the water vapor for different amounts of the latter and for different altitudes of the sun above the horizon. It may be noted that the graphs are averages of a number of individual determinations of the sun's energy and that variations from this distribution are to be expected.

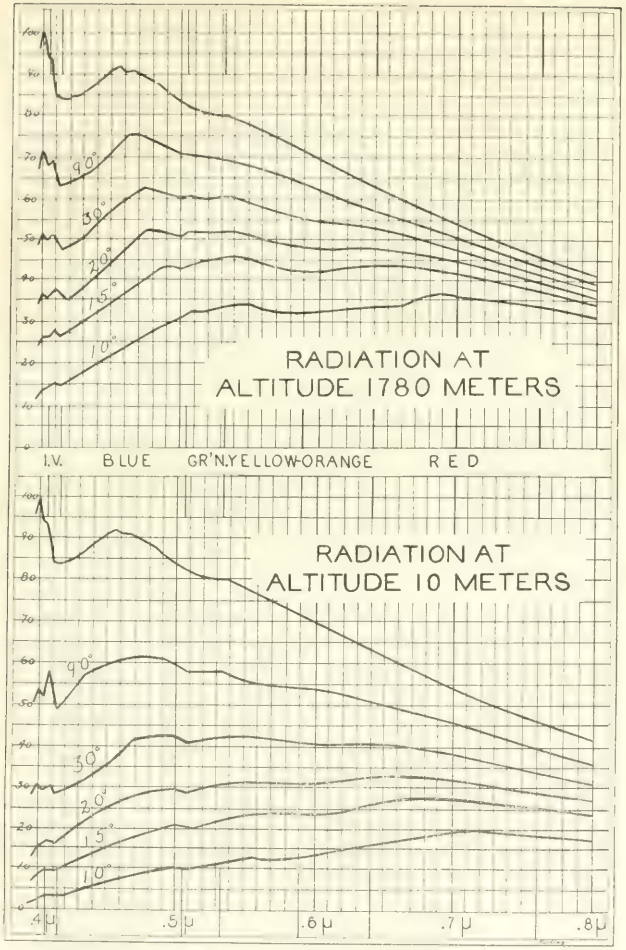

Fig. 4. Graphs exhibiting the effect of the length of atmospheric path upon solar radiation. The upper curve in each set of graphs is that for extra-atmospheric radiation; the others are for radiation with the sun at the altitude marked on the graph.

THE RÔLE OF TEMPERATURE IN THE DETERMINATION OF THE TRANSPIRING POWER OF LEAVES BY HYGROMETRIC PAPER

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In the investigation of the transpiration of plants there are obvious advantages in being able to determine the rates of water loss from the leaves of entire plants growing in the soil or in their natural habitats, as contrasted with the use of severed shoots or potted plants. This advantage has led Livingston to revive the cobalt chloride method of Stahl, in which dried slips of paper impregnated with this salt are placed next to the leaf and the time is observed which is required for the change from blue to pink. Livingston[1] has improved the technique of Stahl's method and has provided for the standardization of the readings secured by ascertaining the time required for the color change over a free water surface. A further improvement in the method has been made by Livingston and Shreve[2] in the devising of a tripartite slip, in which pieces of paper of two shades of fixed blue are placed alongside the piece which is subject to color change. The attainment of a uniform color change in all tests is thereby ensured.

One of the greatest problems in employing this useful method has arisen from the important influence that temperature has upon the rate of absorption of moisture by cobalt chloride. The solution of this problem, with the exception of one difficulty, has been given by Livingston and Shreve.[3] This difficulty is described by them as follows:

[1] Livingston, B. E., The resistance offered by leaves to transpirational water loss. Plant World, **16**: 1-35. 1913.

[2] Livingston, B. E. and Shreve, E. B., Improvements in the method for determining the transpiring power of plant surfaces by hydrometric paper. Plant World **19**: 287-309. 1916.

[3] Livingston, B. E. and Shreve, E. B., Idem.

It should also be emphasized that . . . . the whole method of standardized hygrometric paper slips . . . . is based on the supposition that the papers lying upon the plant leaves are under the influence of the temperature of the air about the plant . . . . as soon as leaf temperature can be measured conveniently it will be necessary to employ these readings instead of those taken on a thermometer simply exposed beside the plant. . . . . Even such a procedure as this may eventually require correction, for the temperature influence exerted upon a slip lying upon a leaf and covered by a glass plate must be determined by the temperatures of leaf and plate together.

The rôle of leaf temperature in the determination of the transpiring power of leaves has two aspects, one being the part played by the temperature of the slip in the calculations which must be performed to determine the index of transpiring power, and the other being the effect produced on the transpiring power of the leaf by any change in the leaf temperature which may be caused by the application of the clip. This paper is concerned only with the first one of these aspects.

The work[4] of A. L. Bakke, Aleita Hopping and of S. F. Trelease and B. E. Livingston has shown that the times of color responses of the cobalt paper are inversely proportional to the maximum vapor pressures of water corresponding to their respective temperatures. Consequently it is very important that the temperature of the cobalt slip be known when the test is taken.

A convenient method for the determination of leaf temperatures[5] has now been worked out and a slight modification of it has made it possible to measure the temperature of the slip as it lies on the leaf surface covered by slip and glass plate.

Figure 1 represents the glass clip,[6] which is used to hold the tripartite slips on the leaf, carrying a small thermo-couple (*a*, *b*) on the inside of one plate. The wires are fastened to the plate by means of a piece of gummed cloth (*c*) pasted to the outside.

[4] For references see Livingston and Shreve, loc. cit. p. 298–9.

[5] Shreve, E. B. A thermo-electrical method for the determination of leaf temperatures. Plant World **22**: 100–104, 1919.

[6] For the original description of the clip see Livingson, B. E. The resistance offered by leaves to transpirational water loss. Plant World **16**: 8. 1913.

The tripartite slip is placed between the glass and wire, so that the thermal junction comes next to the leaf. On the outside a rectangular hole is cut in the gummed cloth so that the tripartite slip can be seen from the outside as usual. The thermal-couple is made of copper and "Ideal" wires, both being no. 40, the piece of soldering at the junction being no thicker than the wires. The wires have such a small diameter that the glass clip fits practically as tightly as without it. The galvanometer and other parts of the apparatus for determining the temperature have been previously described in detail.[7]

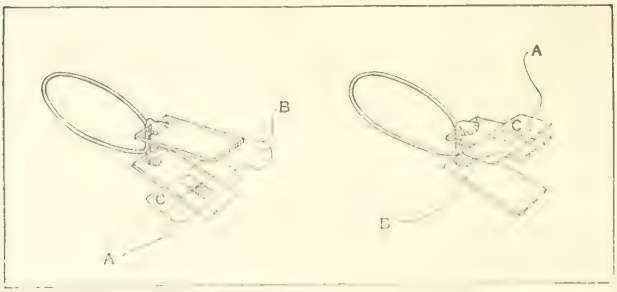

Fig. 1. Upper and lower views of cobalt chloride clip showing arrangement for use of thermo-couple.

Tests were made on widely different types of plants, growing both in the greenhouse and in the open. The clip, arranged as in figure 1, was placed on the leaves and left there while the cobalt paper turned from the light to the dark standard blue and the temperature was read every ten seconds during this time. Tables 1 and 2 give samples of the results obtained. The temperature of the slip departs somewhat from the air temperature by different amounts according to the species of plant, time of day and the atmospheric and soil conditions. However the greatest departure from air temperature, as read by a mercury thermometer, which appeared in all the tests was 1.5 C. and this occurred only for temperatures above 28°C.

[7] Shreve, E. B., loc. cit. 1919.

TABLE 1

Departure from air temperature, shown by cobalt slips when resting on plant leaves and covered by a glass clip. Potted plants growing in greenhouse, May 10–11, 1918

PLANT	SURFACE	TIME	TEMPERATURE AIR BEFORE	TEMPERATURE AIR AFTER	DIFFERENCE FROM AIR TEMPERATURE OF COBALT SLIP AT END OF NUMBER OF SECONDS INDICATED										
					25	10	20	30	40	50	60	70	120	180	240
			°C.	°C.											
Lantana	Lower	10 00 p.m.	22.6	22.6	+0 6	+0.2	−0 2	−0 4	−0 6	−0 6	−0 6	−0 6	−0.6		
	Upper	10 00 p.m.	22 6	22.4		+0 2	+0 2	0 0	0.0	0 1	0 1	0 1			
Poinsettia	Lower	10 15 p.m.	21 9	21.9				+0 1			−0 2		−0 2	−0 2	−0.4
	Upper	10 20 p.m.	21 9	21.5				0 0			0 0		0 0	0.0	0.0
Rumex	Lower	10 25 p.m.	21.5	21 5				0 0			0.0		0 0	0 0	0.0
	Upper	10 30 p.m.	21 5	21.2				−0 3			0 3		−0 3	0 3	
Crucifer	Lower	10 35 p.m.	21 0	20 7	+0 2			+0 2			0 0		0 0	0 0	0.0
	Upper	10 40 p.m.	20 7	20 5				0.0			+0 2		+0 2	+0.1	+0.1
Nasturtium	Lower	11.45 p.m.	20 5	20 2	+0.3			+0 3			+0 3		0 0	0 0	
	Upper	11 50 p.m.	20 3					0 0			0 0		0 0		
Lantana	Lower	12 N.	19 2	19.2	+0 3			+0 3			+0 3		+0 2	+0 2	+0.1
	Upper	12 05 a.m.	19 3	19.2		+0.2		+0.2			+0 2		+0 1	0 0	
Poinsettia	Lower	12 10 a.m.	19 1	18.7				0 0			−0 2		0 0	0 0	
Rumex	Lower	12 15 a.m.	18.7	18 8		+0.3		+0.3			+0 3		+0 3	+0 2	
	Upper	12 20 a.m.	18.8	18.8				+0 3			+0 3		+0 2	+0.2	
Crucifer	Lower	12 25 a.m.	18 8	18 8				0.1			0 1		−0 1	0 0	
	Upper	12 30 a.m.	18 8					0.0			0 0		0 0	0 0	
Nasturtium	Lower	12 35 a.m.	18 3					+0.4			+0 4		+0.4	+0.4	
	Upper	12 40 a.m.	18 3					+0 4			+0 4		+0 4	+0 4	
Lantana	Lower	4 00 a.m.	15.7	16.2				+0.4			+0 2		+0 5	+0 5	
Poinsettia	Lower	4 05 a.m.	16 2	16.1				+0.4			+0 3		+0.3	+0.3	
Rumex	Lower	4.10 a.m.	15.9	16.4				+0.3			+0 3		0.0	0.0	
Crucifer	Lower	4 15 a.m.	16 6	16.7				0 0			0 0		0.0	0.0	
Lantana	Upper	2 00 p.m.	31.5		0.0	−0.1	−0.2								
	Lower	2 02 p.m.	31 8		+0 3	+0.2	+0.1	0.0	+0.1	+0.1					
Tradescantia	Upper	2 05 p.m.	31.2	31.3				+1.3			+0 8		+0.3		+0.0
	Lower	2.10 p.m.	31.6		+0.4	+0.2	+0.1	−0.1	−0.1						

Following is a list of plants for which indices of transpiring power have been calculated,[8] using first the temperatures as read from a shaded mercury thermometer standing in the foliage of the plant, and second, the temperatures obtained by the thermo-couple. In the second case the reading which showed the maximum difference from air temperature was always used.

GROWING IN THE OPEN	GROWING IN POTS
Encelia farinosa	*Encelia farinosa*
Prosopis velutina	*Lantana* sp.
Fouquieria splendens	*Poinsettia* sp.
Amaranthus palmeri	*Phaseolus* sp.
Bahia absinthifolia	*Rumex hymenosepalus*
Streptanthus arizonicus	*Nasturtium* sp.
Malva borealis	*Ricinus officinale*
	Tradescantia sp.
	Amaranthus palmeri
	Streptanthus arizonicus

In no case does the second result differ from the first more than 10%, and in the majority of cases it is under 2%. Now the maximum difference between the indices of 10 different leaves of the same apparent age on the same plant is frequently over 20% and never under 10%. Consequently this work has established the fact that the temperature of the air may be safely used for the temperature of the cobalt slip. A sample of the results is given in table 3.

It is of course just as important to know whether or not the air temperature may be used instead of the temperature of the slip, in the calculations for the standardization of the slips over a porous evaporating surface. By fastening the thermal couple to a microscopic slide in the same manner that it is fastened to the glass of the spring clip in figure 1, the temperature of the slip as it lies over the evaporating surface was read. The porous evaporating surface used was similar to the one described by Livingston and Shreve[9] with the exception that a thermometer bulb was not inserted in the side. In table 4 are given the times required for

[8] For method of calculation see Livingston and Shreve, loc. cit. p. 306. 1916.
[9] Livingston and Shreve, loc. cit. p. 294. 1916.

the slips to make their color change at 20° C. when calculated from temperatures obtained from the thermal couple touching the slip, and from a mercury thermometer hung near the apparatus.

Temperatures were thus read for slips from 18°C. to 27°C. at one degree intervals, the readings being made every ten seconds. In table 4 appear representative examples of these readings. In order to discover the effect which the differences of temperature shown in the tables will have upon the calcula-

TABLE 2

Departure from air temperature shown by cobalt slips when resting on plant leaves and covered by a glass clip. Plants growing in open in situ.

PLANT	SURFACE	TIME	TEMPERATURE AIR BEFORE	TEMPERATURE AIR AFTER	DIFFERENCE FROM AIR TEMPERATURE OF COBALT SLIPS AT END OF SECONDS INDICATED					
					10	20	30	40	50	60
			°C.	°C.						
Encelia	Upper	11.00 a.m.	27.4	27.7	0.0	+0.1	+0.7	+0.7	+0.7	+0.7
	Lower	11.30 a.m.	29.0	28.7	−1.2	−1.5	−1.5	−1.5	−1.3	−1.2
	Upper	2.00 p.m.	32.0	32.0	+1.1	+1.1	+1.2	+1.0	+0.9	+0.7
	Lower	2.10 p.m.	31.9	31.8	−0.2	−0.2	−0.1	0.0	0.0	0.0
	Upper	4.00 p.m.	26.1	26.5	+0.5	+0.7	+0.4	+0.4	+0.2	+0.1
	Lower	4.10 p.m.	26.5	26.3	−0.1	−0.2	−0.2	−0.1	0.0	−0.3
	Upper	12.10 a.m.	16.2	16.2	0.0	0.0	0.0	0.0	0.0	0.0
	Lower	12.15 a.m.	16.2	16.2	0.0	0.0	0.0	0.0	0.0	0.0
Fouquieria	Upper	12.00 M.	32.0	32.2	−0.1	+0.7	+0.8	+0.8	+0.8	+0.8
	Lower	12.05 p.m.	32.2	32.4	−0.6	−0.6	−0.8	−1.0	−1.0	−1.0
	Upper	4.00 p.m.	29.0	29.0	+0.2	+0.2	+0.2	+0.2		
	Lower	4.15 p.m.	28.4	28.5	0.0	−0.3	−0.4	−0.4	−0.5	
	Upper	1.00 a.m.	17.1	17.0	−0.1	−0.3	−0.3	−0.2	−0.2	
	Lower	1.10 a.m.	16.5	16.5	−0.1	−0.2	−0.2	−0.2	−0.2	

tions for determining the transpiring power, it is necessary, first to find the effect they will have upon the standardization of the paper over the porous evaporating surface, and second the influence the differences obtained in standards will have upon the index of transpiring power.

The influence upon the standardization of the paper is shown in table 5. In the case of slip no. 12, the color change was completed in thirty seconds, the average temperature during the interval being 21.1° C. and of the slip 20.7° C. By the use of the

TABLE 3

Effect of using air temperature instead of the temperature of the slip in the calculations for determining the index of transpiring power (T. P.) by means of cobalt paper. The maximum and minimum from ten leaves is given in each case. Pt. I Encelia farinosa growing in the open. Pt. II Lantana sp. growing in pots in the greenhouse.

TIME	SURFACE	INDEX OF T. P. USING AIR TEMPERATURES		INDEX OF T. P. USING TEMPERATURE OF SLIP		AIR TEMPERATURE
		Maximum	Minimum	Maximum	Minimum	
		Part I				
						°C.
12 N	Upper	0.11	0.08	0.11	0.08	26.5
	Lower	0.12	0.07	0.12	0.07	26.5
6 a.m.	Upper	0.14	0.10	0.14	0.10	21.5
	Lower	0.38	0.15	0.38	0.15	21.0
8 a.m.	Upper	0.84	0.73	0.85	0.72	27.5
	Lower	0.77	0.57	0.76	0.56	27.5
10 a.m.	Upper	0.51	0.15	0.47	0.14	35.2
	Lower	0.42	0.22	0.43	0.24	35.0
12 M.	Upper	0.16	0.06	0.15	0.05	40.0
	Lower	0.24	0.06	0.27	0.06	40.0
2 p.m.	Upper	0.30	0.06	0.33	0.06	39.5
	Lower	0.53	0.37	0.55	0.38	39.5
		Part II				
8 a.m.	Upper	0.08	0.04	0.08	0.04	20.0
	Lower	0.35	0.28	0.34	0.28	20.0
10 a.m.	Upper	0.09	0.05	0.09	0.05	23.0
	Lower	0.85	0.41	0.84	0.41	23.0
12 M.	Upper	0.05	0.05	0.05	0.05	28.5
	Lower	0.49	0.32	0.48	0.32	28.5
2 p.m.	Upper	0.04	0.04	0.04	0.04	29.0
	Lower	0.34	0.23	0.33	0.23	29.0
4 p.m.	Upper	0.07	0.05	0.07	0.05	28.2
	Lower	0.14	0.08	0.14	0.08	28.5
12 N	Upper	0.02(−)	0.02(−)	0.02(−)	0.02(−)	21.0
	Lower	0.04	0.02	0.04	0.02	21.1

table of ratios furnished by Livingston and Shreve,[10] it may be calculated that the time for the slip would be 31.9 seconds if air temperature is used, or 31.2 seconds if the temperature of the

TABLE 4

Temperatures of tripartite slips lying over a porous evaporating surface compared with the temperature of the air in the immediate vicinity. Readings taken in a small closed room

	TIME INTERVAL (SECONDS)						NUMBER OF SLIP USED
	10	20	30	40	60	120	
Temperature air by mercury thermometer	21.0	21.1	21.1	21.1	21.1	21.2	12
Temperature slip by thermo-couple	20.8	20.7	20.6	20.5	20.5	20.5	
Temperature air by mercury thermometer	25.0	25.1	25.2	25.4	25.5		16
Temperature slip by thermo-couple	25.3	24.2	24.1	24.1	24.0		
Temperature air by mercury thermometer	26.2	26.2	26.2	26.2	26.3		18
Temperature slip by thermo-couple	26.0	26.0	26.0	26.0	26.2		
Temperature air by mercury thermometer	27.1	27.1	27.0	27.1	27.2		25
Temperature slip by thermo-couple	27.5	27.5	27.4	27.3	27.3		
Temperature air by mercury thermometer	18.0	18.1	18.2	18.2	18.3		48
Temperature slip by thermo-couple	17.9	17.8	17.8	17.7	17.7		

TABLE 5

Calculated time for color change to be completed at 20°C. on various cobalt slips using (A) the temperature of the air as read by a mercury thermometer, and (B) the temperature of the slip as determined by the thermo-couple

NUMBER OF SLIP	A	B
	seconds	*seconds*
12	31.9	31.2
16	32.9	32.4
18	31.4	31.9
25	31.8	32.8
48	31.2	30.5

slip is used. The times for the other slips were calculated in the same way. The effect of these differences in the results of the standardization, upon the index of transpiring power is shown

[10] Livingston and Shreve, loc. cit. p. 305. 1916.

in table 6. Numbers have been selected which will show the greatest possible variation for plants and then used with the slip no. 25, the one which showed the greatest difference in its standards. Thus if the color change took place in slip no. 25 in a given plant in 16 seconds at 35°C., then the index of transpiring power would be 0.86 with 32.8 as standard and 0.83 with 31.8 as standard.

By reference to the maxima and minima for transpiring power given in table 3, it is seen that the error obtained by using the air temperature instead of the temperature of the slip in the standardization over a porous surface is entirely negligible in the light of the differences which are obtained on the plants themselves.

TABLE 6

Effect upon the index of transpiring power of using two different standards for the cobalt slip, the differences in the standards having been obtained by the use of (1) air temperature, (2) temperature of the slips

TIME FOR COLOR CHANGE AT TEMPERATURE INDICATED	INDEX OF TRANSPIRING POWER	
	1	2
	32 S as standard at 20°C	31 S as standard at 20°C.
16 seconds at 35°C	0.86	0.83
180 seconds at 35°C	0.08	0.07
16 seconds at 15°C	2.80	2.72
180 seconds at 15°C	0.25	0.24

SUMMARY

1. In the determination of the index of transpiring power by tripartite cobalt slips no error requiring consideration is introduced into the calculations by using the temperature of the air immediately surrounding the leaf instead of the temperature of the slip itself.

2. In the standardization of the tripartite cobalt slips over a porous evaporating surface in a small closed room, the temperature of the air near the apparatus may be used instead of the temperature of the slip itself.

BOOKS AND CURRENT LITERATURE

PLANT GENETICS. A recent addition[1] to the series of texts from the Botanical Department of the University of Chicago indicates by its appearance the increasing demand from students in biology for instruction in genetics. The purpose of the book can be judged by quotations from the preface. "The group that the present book is intended to serve primarily comprises those who intend to make botany their profession and who, although not as yet specialists, have had general training in the fundamentals of botany. Such students, for example, are commonly found in the last undergraduate year or the first graduate year of their work with no distinct purpose to become geneticists, but wishing to be able to appreciate the important current work in plant genetics." . . . . "The purpose of the lectures was not to develop professional geneticists, but merely to initiate students of botany into the point of view of working geneticists, so that they could appreciate an important phase of botanical literature. . . . . There was no attempt to give a complete presentation of modern genetics, but rather to introduce the student to genetics in the simplest way. As a consequence, for pedagogical reasons, certain perplexing facts were omitted, while others were slightly adjusted so as to convey the fundamental ideas without confusion." . . . . "As a textbook . . . . it has two disadvantages: (1) it is avowedly not exact in some of the details; (2) it is adapted definitely to young botanists with fairly thorough elementary training. The excuse for the inexactness of certain details is the pedagogical necessity. The preparation of a text for the students referred to is explained by the fact that it represents a very important group which has not been provided for. In brief, the book is neither a technical presentation of genetics nor a general text, but a course of general lectures adapted to a special purpose."

The series of lectures embodied in the text were obviously written from the standpoint of a botanist. In the first part of the book the well-known facts and theories of genetics are briefly sketched and their

[1] Coulter, John M. and Merle C. Plant Genetics. Pp. 214, figs. 40. University of Chicago Press, 1918.

relation to botanical information familiar to the student is pointed out. Frequent diagrams illustrate the text but half-tones are avoided. Quotations in large and small type, chiefly from East, are used freely throughout. The latter part of the book is less elementary than the first and the method of treatment more like what one would expect if the title had been "Problems in Plant Genetics." The chapter on "Inheritance in Gametophytes," for example, contains an interesting discussion of a topic largely neglected by more ambitious text books of genetics. The professional geneticist might expect in a text of this size a somewhat greater reliability in details and a more extended discussion of the established facts with a less extended discussion of problems suggested to a botanist. He will, however, find the book stimulating reading. Botany, in fact, is the fundamental science. It is unfortunate that there have been some who have seemed to act upon the belief that forestry, plant pathology and plant genetics are subjects unrelated to botany. Coulters' Plant Genetics will be found of value in advanced departments of botany like that in the University of Chicago.—A. F. Blakeslee.

Proliferation in Cacti.—The peculiar behavior of the fruits in certain species of cacti has been investigated by Johnson,[1] with particular reference to proliferation in *Opuntia fulgida*. The fruits of *Opuntia* and two closely related genera are unlike those of all other flowering plants in the possession of abortive leaves with functional axillary buds. In *Optunia fulgida* the withering stamens and petals are separated from the ovary by a definite abscission layer, but the maturing of the seeds fails to produce any of those changes in the fruit which are almost universal among higher plants: there is no ripening nor change of color, there is no form of dehiscence, there is no separation of the fruit from its parent stem, and there is frequently a continuation of growth. The axillary buds, or areoles, of the fruit regularly produce trichomes and nectaries, frequently produce flowers, and in very rare cases give rise to vegetative shoots. The persistence of the fruits, and their proliferation from one to four times a year, results in heavy pendent clusters. These are eagerly eaten by cattle but reach a length of 12 to 18 inches on undisturbed plants. The early development of the ovary in *Opuntia fulgida* is found to resemble that of a

[1] Johnson, Duncan S. The Fruit of *Opuntia fulgida*: a study of perennation and proliferation in the fruits of certain Cactaceae. Carnegie Inst. Wash. Pubn. 269. Pp. 62, pls. 12. 1918.

vegetative shoot, the wall of the ovary being a stem in its morphological origin. The author believes that the ovary of this cactus was superior in its primitive condition, and that its present inferior position is due to gradual submergence of the stem-like fertile shoot by the active growth of the surrounding parts. The seeds retain their viability for many years but will not germinate without the puncturing of their heavy coats. Since this is the only known case in which seeds persist for years in a fruit which remains moist, an ingenious experiment was devised in which filed seeds were again placed in fruits, with moisture and temperature conditions favorable for germination, but no activity resulted. Sterile seeds are frequent but are not outwardly distinguishable from fertile ones. Seedlings are unknown in nature, the perpetuation of the plant depending chiefly on the dissemination of the readily detached and easily rooted vegetative joints. The fruits which fall to the ground no longer possess the ability to give rise to flowers, but take root, under favorable conditions, and produce vegetative shoots. The author states that there is no evidence to indicate that *Opuntia fulgida* is on the road toward a loss of the power of seed production and a total dependence on vegetative multiplication, but it is difficult to follow his reasoning in this particular.

The publication is amply illustrated both with respect to the gross features of the fruits and the anatomical development of the fruit, flower, and accessory parts, and the work as a whole constitutes a very thorough investigation of one of the most striking cases of aberrant floral behavior among our native plants.—Forrest Shreve.

NOTES AND COMMENT

An important contribution has been made to our knowledge of the botany of the antarctic islands by T. F. Cheeseman, of the Auckland Museum, who has worked up the plants collected by Sir Douglas Mawson's expedition in Macquarie Island. This small island is situated 600 miles south-west of New Zealand and is widely remote from the nearest land in the same latitude. The climate is moist but the temperature extremely equable, having an annual mean daily range of only 5.6°F. The flora consists of only 34 species, of which 3 are endemic grasses and 27 others plants that are common to the New Zealand Subantarctic Islands. Fifteen of the species are circumpolar in distribution and are among the commonest components of the vegetation in this island, in South Georgia, 5800 miles to the east, and in Kerguelen, 3250 miles to the west. The Antarctic continent has at present only two species of flowering plants, so far as known, but such evidence as this points to its having formerly been a highway of dispersal.

Several papers have been written by Mr. Wilson Popenoe describing the achievements of a year which he recently spent in Guatemala, exploring all parts of that country in quest of varieties of avocado suitable for introduction in the United States. This nutritious fruit is one of the chief articles of diet among the Guatemalan Indians, and the avocado tree is found at all elevations from sea level to 8500 ft. The three races and numerous varieties found at different altitudes were carefully studied by Mr. Popenoe, and bud-wood of the most promising ones was successfully shipped to Washington. Everyone who has tasted this delicious fruit will hope that its successful cultivation in this country will be greatly aided by this important piece of horticultural exploration. The cultivation of avocadoes is now being carried on in Florida and California, but the industry is still in such a stage as to justify the high prices that are asked for the home grown fruit.

The dry glasslands of mixed composition, which occur at all altitudes in the Rocky Mountains from the edge of the plains to 11,000 ft., have been investigated by Dr. Francis Ramaley (Bull. Torr. Bot. Club,

Feb. 1919). The conditions become more mesophytic with increasing altitude and the temperatures of air and soil at 11,000 ft. range from 48° to 58°F. in July and August. The entire flora of the dry grasslands is tabulated so as to show the occurrence of each species in the five altitudinal zones commonly recognized. There is considerable similarity between the base of the mountains and the montane zone, but very few species of the former region reach the alpine zone. A number of species found only in moister situations at the lower altitudes are found to enter the dry grasslands at higher elevations, on account of the influence of lower temperature as well as of the higher soil moisture at the commencement of the growing season.

Dr. M. J. Dorsey, of the Minnesota Experiment Station, has contributed a paper to the Journal of Agricultural Research on the relation of weather to fruitfulness in the plum, showing that rain, low temperatures and strong wind all interfere with the setting of fruit. Rain interferes with the dissemination of pollen by closing the anthers or preventing them from opening. Frosts injure the pistil more than the pollen, but the chief effect of low temperatures is in retarding the growth of the pollen tube. High wind interferes with insect action and is not in itself capable of effecting full pollination. The fact that plum pollen will retain its germinating power for six months, if kept under favorable moisture and temperature conditions, suggests the possibility of artificial pollination in certain cases.

SUNLIGHT AND ITS MEASUREMENT

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II. MEASUREMENT OF SOLAR RADIATION

It is plain from the foregoing data that sunlight is not even approximately an invariant constant either in quantity or quality at any station of observation on the earth's surface. It follows that for biological experimentation in which it is desired to ascertain the influence of radiation, resort must be had to artificial illuminants, appropriately controlled, or else the incoming radiant energy must be constantly measured.

It is not a part of the plan of this paper to enter into a discussion of artificial illuminants although for those interested a bibliography that seems to be sufficiently extensive to meet the initial needs of biologists is included.[55] It may, however, be noted that the behavior of the more recent types of electric

[55] Pirani, M. von, and A. R. Meyer, Über die neueren elektrishen Glühlampen mit Gasfüllung. Elektrotech. Z. **36:** 493–496; 507–510. 1915.

Mey, K., Die Nitralampe der Allgemeinen Elektricitäts Gesellschaft. Elecktrotech. Z. **36:** 376–377. 1915.

Middlekauff, G. W., and J. F. Skogland, The photometry of gas filled lamps. U. S. Bur. Standards Sci. paper 264: 587–604. 1916.

Robinson, R. C., Candle power measurements of a series of gas filled incandescent tungsten lamps. Trans. Illum. Eng. Soc. **11:** 187–191. 1916.

Tuck, D. H., Photometry of gas filled tungsten lamps. Elec. World **65:** 78. 1915.

Mackay, G. M. J., The characteristics of gas filled lamps. Trans. Illum. Eng. Soc. **9:** 775–794. 1914.

Hulburt, E. O., The emissive power of tungsten for short wave lengths. Astrophys. J. **45:** 149–163. 1917.

Rolinson, W. H., New types of incandescent lamps and their relation to the street lighting problem. Trans. Illum. Eng. Soc. **11:** 269–281. 1916.

Merrill, G. S., Incandescent lamp developments. Trans. Illum. Eng. Soc. **11:** 525–538. 1916.

Other references will be found scattered through the remainder of the paper.

lamps can be stated with a degree of accuracy sufficient for very good work of at least a preliminary nature without resorting to measurements of the radiation emitted by them after they are installed. It is of course necessary that the current upon which they are operated be sufficiently constant for the needs of the particular case in hand. New lamps fluctuate in emissive power for a time and then assume a very nearly constant state which persists during almost the entire remaining life of the lamp (with the vacuum tungsten lamps, until blackening of the glass is serious, with the globular gas-filled lamps properly placed, practically until the filament breaks) especially if they are operated below their maximum brilliancy.

Turning from this digression to the main topic -the methods for the measurement of the sun's radiation- it is necessary to note that before selecting an instrument it is essential that the investigator decide just what feature of the incident radiation he desires to measure. The time has gone by when the choice of instruments is simply made; for unless we know what features of the sun's radiation we wish to measure and the applicability of the method selected, the acquirement of useful results is purely accidental, regardless of the care exercised in using the method. Often very rough measurements from the physicist's standpoint yield valuable results in biology and very sensitive instruments may give data that are wholly erroneous. Scientific data are, of course, no more accurate than the *net* accuracy of the *entire* method, and to measure radiation with a precision of 1% while the corresponding observations on the plants vary to 30% or more not only entails sheer waste of time but is misleading and hurtful to scientific progress. On the other hand, the idea that any instrument is as good as any other for rough preliminary research as all botanical radiation work will be in the near future is also wrong because the instrument may not measure at all the component of radiation that is effective in the biological process under consideration. The photographic actinometer, when used to obtain a measure of the amount of energy available to plants for photosynthesis, is a case in point.

After deciding what feature of radiation it is desired to measure and what degree of accuracy is necessary, the instrument must be selected with these purposes in mind as well as with an appreciation of the conditions under which the measurements are to be performed, in order that both errors of manipulation and errors of interpretation may be guarded against. There are many excellent methods for measuring radiation. All have their advantages and disadvantages and simplicity of operation is not the only criterion by which they should be judged. The most sensitive and the most precise instruments have peculiarities that can only be successfully met by sufficient experience in their manipulation, so that for only occasional use for brief periods they should not be selected. It may be added that the most sensitive instruments do not necessarily yield the most accurate results. Such instruments are usually delicate and with careless treatment or in the hands of persons ignorant of their principles of construction they may give results more at variance with the truth than less precise apparatus. It is unfortunately too common in biological literature to find work published that is wholly misleading in its implications and expressed statements of accuracy because the author refined one portion of the method adopted to a high degree and completely ignored sources of large error in other portions. The growing use of the "probable error" is to be deplored on that account: that observations agree among themselves is no guarantee of the correctness of the results and an account of investigations of the instrumental and experimental errors would be far more convincing and of real value.

There are three general methods for measuring radiation and each has been developed along several lines so that the subject is complicated both because of its terminology (which, it may be added, is not in all cases either stable or rational) and because each instrument has certain disadvantages and advantages depending upon the purpose for which the user intends it. Although it is out of the question to present this extensive subject in any detail, still it seems that a good purpose will

be served by attempting a brief exposition of the scope of each general field with a few notes on some of the essential working features of the instruments so that, with the aid of the discussions to which references are made, those interested may be aided in their selection.

1. *Radiometry*

Experience has shown that all energy is completely transformable into heat energy—one of the principles upon which thermodynamics is based. Radiometry consists in converting

[26] Boys, C. V., Preliminary note on the radio-micrometer, a new instrument for measuring the most feeble radiation. Proc. Roy. Soc. London **42:** 189–193. 1887.

Idem. The radio-micrometer. Phil. Trans. Roy. Soc. London **180A:** 159–186. 1889.

Wilson W. E., The thermal radiation from sun spots. Proc. Roy. Soc. London **55:** 246–249. 1894.

Nichols, E. F., A method for energy measurements in the infra-red spectrum and the properties of the ordinary ray in quartz for waves of great wave length. Phys. Rev. **4:** 297–313. 1897

Abbot, C. G., Ann. Astrophys. Obs. Smithsonian Inst. **2:** 1908; **3.** 1913.

Langley, S. P., The bolometer and radiant energy. Proc. Amer. Acad. Sci. **16:** 342–358. 1881.

Idem Ann. Astrophys. Obs. Smithsonian Inst. **1.** 1902.

Coblentz, W. W., Instruments and methods used in radiometry. I. Bull. U. S. Bur. Standards **4:** 391–460. 1908.

Idem. II. Bull. U. S. Bur. Standards **9:** 7–63. 1913.

Idem. Measurements on standards of radiation in absolute units. Bull. U. S. Bur. Standards **11:** 87–100. 1915.

Idem. Constants of spectral radiation of a uniformly heated enclosure or so-called black body. I. Bull. U. S. Bur. Standards **10:** 1–77. 1914.

Idem. II. U. S. Standards **13:** 459–477. 1916.

Hyde, E. P., and F. E. Cady, On the determination of the mean horizontal intensity of incandescent lamps by the rotating lamp method. Bull. U. S. Bur. Standards **2:** 415–437. 1906.

Idem. On the determination of the mean horizontal intensity of incandescent lamps. Bull. U. S. Bur. Standards **3:** 357–369. 1907.

Coblentz, W. W., and W. B. Emerson, Studies of instruments for measuring radiant energy in absolute value. An absolute thermopile. Bull. U. S. Bur. Standards **12:** 503–551. 1916.

Abbot, C. G., and L. B. Aldrich, The pyranometer—an instrument for measuring sky radiation. Smithsonian Misc. Coll. **66:** No. 7. 1916.

Idem. On the use of the pyranometer. Smithsonian Misc. Coll. **66:** No. 11. 1916.

the incident radiation completely into heat and measuring the heat thus obtained either directly in heat units (absolute units) or indirectly in terms of its effects (arbitrary or relative units) which may, after the necessary calibration of instruments and computation of results, be re-stated in heat units. There is no actual line separating heat and radiation of shorter wave lengths so that thermometry is logically a branch of radiometry. Likewise the very short waves, those termed in the old text-books "chemical" or "actinic,"[37] and the ultra-violet rays are convertible into heat, so that if the radiometric instrument is sufficiently sensitive or the radiation is sufficiently intense the energy in these high frequencies also may be measured with it.

Because the principle upon which radiometry is based is valid for radiations of all wave lengths, this general method has a greater range of applicability than either of the other two. However, for the reason that it is usually applied to investigations demanding great precision the instruments are often delicate and complicated but this need not be so for work where a very high degree of accuracy is not required. These instruments all consist essentially of a receiver for completely converting the incident radiation into heat and a device for indicating the amount of heat or of its effects.

All receivers must depend upon a surface for the initial absorption, and all surfaces are subject to losses from reflections, radiation and convection. A surface that is, to the eye, absolutely black of course loses almost no visible radiation, but it should be noted that some surfaces that appear black in *diffuse* light may reflect a *beam* of light quite completely, especially when the angle of incidence approaches that of total reflection. Besides providing that the instrument selected shall be an adequate absorber of energy it is necessary to see

[37] One is astonished at the persistent adherence to the conception of a distinction between "chemically active" and "non-chemically active" radiation on the basis of wave length that is shown in modern botanical literature, especially when one recalls that even Sachs (Sachs, Julius, Vorlesungen über Pflanzen-Physiologie, p. 367. Leipzig 1882) insisted upon its erroneous character

that it is protected against losses by convection, especially convection losses due to extraneous air currents, that it is sufficiently uniform over its entire extent or that the radiation is incident always upon the same portion, and that it is placed in the position most favorable for the reception of radiation (*i.e.*, in the plane at right angles to the direction of every ray incident upon it), for any other position, by decreasing the efficiency of the surface, may seriously affect the results. The effects that all the devices, intended as protection to the instrument, have upon the incoming radiation must be sufficiently well known to insure the requisite accuracy. The extent, character and rate of change of the surface with time must be definitely known not to exceed the limits of allowable variation or else the instrument must be re-standardized with sufficient frequency to meet this requirement. If auxiliary mirrors are employed the difficulties increase because of refraction in the mirror, intensified by the bending under intense illumination, defective reflecting surfaces, selective absorption and selective reflection. Mirrors offer exceptional difficulties in many cases, for example in measuring sky radiation, because such radiation is polarized and is liable to partial extinction upon reflection.

The heat capacity of the entire instrument should be small in order that the heat received may promptly produce as near the maximum temperature effect as is desired. Conduction losses between the receiving surface and the indicating device should be kept within desired limits.

The simplest instruments of this type are modifications of the Arago-Davy actinometer,[58] a pair of thermometers, one with blackened and one with unblackened bulb, either exposed or in a vacuum. There are many sources of serious error to be investigated before they can be accepted as of any value although the principle is correct.

Instruments depending upon the utilization of the heat developed for the vaporization of liquid may prove to be of value

[58] Lecq, M. A., L'Actinomètre Arago-Davy. Dehérain Ann. Agron. **4**: 510-530. 1878.

in certain cases if the instrument is so constructed that both vapor and liquid are confined. Freely evaporating surfaces are so readily affected by air currents and the large heat capacity created by a sufficiently large reservoir of liquid that they seem to be of little or no value at present. The question of the greater effectiveness of some wave lengths than others, still further militates against their use as does also the dependence of rate of evaporation upon the temperature of the surface. Until these features have been taken into account all instruments depending upon vaporization can only yield results that are open to question.

Instruments depending upon temperature changes in electrical resistance have been investigated in great detail. Each has its own weaknesses and merits for which the references, especially the excellent comparative discussion by Coblentz,[39] should be consulted. Although none are very easy to operate the pyranometer, the Rubens linear thermopile and its modifications and the radiomicrometer should prove useful in biological research.

Instruments depending upon volume changes of liquids and gases are influenced by the prevailing temperature of the surroundings, and are limited in usefulness by the transmission of their containers and the nature of the thermo-sensitive substance employed. They are of course essentially like the Arago-Davy actinometer. One instrument at least of the type depending upon temperature effects upon gases the Nichols radiometer is, unlike the majority, useful for spectrum work and, although not portable, it is extremely simple of operation and may be built to have a very high degree of sensitiveness. It has been rather thoroughly investigated by Coblentz. Some of the instruments appear to be still susceptible of improvement and those employing thermo-couples could undoubtedly be sufficiently simplified to permit of general use where a high degree of sensitiveness is not required. It may be noted that if an instrument is selected that necessitates a galvanometer, the peculiarities of the latter must be considered separately

[39] Coblentz, W. W., Instruments and methods, etc., I and II, cited in [illegible]

with reference to the conditions under which it is proposed to use it. In conclusion, a "thermo-galvanometer" described by Jordan[1] deserves mention as a relatively simple device for some purposes.

2. *Photometry*[2]

Because the human eye is sensitive to differences in illumination it has been utilized as a photo-sensitive instrument, defining light, not in energy units, but in units of physiological effect—brightness. For this purpose a light of known intensity is required, which is varied in a known way until it produces an illumination that is equal to that produced by the source under investigation.

[1] Jordan, F. W., On a new type of thermo-galvanometer. Proc. Phys. Soc. London **26:** 165–171. 1914.

[2] 1918 report of the committee on nomenclature and standards of the Illuminating Engineering Society. Trans. Illum. Eng. Soc **13:** 512–523. 1918.

Rosa, E. B., Photometric units and nomenclature. Bull. U. S. Bur. Standards **6:** 543 572. 1909 1910.

Ott, E., Variation of Hefner lamp with atmospheric conditions. J. Gaslighting **132:** 378–381. 1915.

Hyde, E. P., and W. E. Forsythe, Visibility of radiation in red end of visible spectrum. Astrophys. J. **42:** 285–293. 1915.

Blanchard, J., The brightness sensibility of the retina. Phys. Rev. **11:** 81–99. 1918.

Coblentz, W. W., and W. B. Emerson, Distribution of energy in the visible spectrum of the acetylene flame. Bull. U. S. Bur. Standards **13:** 355–364. 1916.

Idem. Selective radiation from various substances. Bull. U. S. Bur. Standards **7:** 243 294. 1911.

Palaz, A., A treatise on industrial photometry with special application to electric lighting. Trans. G. W. Patterson. 2nd. ed. New York. 1896.

Patterson, C. C., Investigations on light standards and the present condition of the high voltage glow lamp. Proc. Inst. Elect. Eng. **38:** 271–348. 1907.

Idem. The proposed international unit of candle power. Proc. Phys. Soc. London **21:** 867 883. 1909.

Troland, L. T., Apparent brightness; its conditions and properties. Trans. Illum. Eng. Soc. **11:** 947–975. 1916.

Nutting, P. G., Effects of brightness and contrast in vision. Trans. Illum. Eng. Soc. **11:** 939 946. 1916.

Barrows, W. E., Light, photometry and illumination. New York. 1912.

Wickenden, W. E., Illumination and photometry. New York. 1910.

Ives, H. E., The primary standard of light. Astrophys. J. **36:** 322–329. 1912.

Because light sources are usually used only to render objects visible, the measurement of their illuminating power in terms of that of some standard source has come to be of importance quite independently of any question of the actual energy emitted by these sources. Thus photometry deals with meter candles and lumens as its units instead of employing units of energy. If the light sources are of the same kind so that the quality of radiation is closely similar, the actual energy values may be readily obtained once that of the primary standard is known. If, however, the light sources are different the question of the light quality becomes of great importance if energy statements are desired, because the human eye is not equally sensitive to all visible radiation. Furthermore the sensitivity curve of the human eye changes with changes in the intensity of illumination in such a way that as the intensity of illumination decreases the maximum sensitivity shifts toward the shorter wave lengths. Besides these difficulties there are the added ones of the influence of the pupil area (changing the amount of light received by the eye), the psychological effects of contrast, etc., and the physiological state of the observer. These various influences have received detailed consideration and many devices have been adopted for particular purposes, for which the special texts and journal articles should be consulted.

One device deserves special mention because, besides being widely used in photometry, it has been suggested for radiometry and actinometry as well the rotating sectored disk for reducing light intensity. Its use is based on Talbot's law[2] that upon intermittent illumination of sufficiently short periods of interruption the human eye integrates the effect by a simple

[2] Talbot, W. F., Experiments on light. Phil. Mag. (3) **5**: 321–334. 1834.

Wiedemann, E., Ueber Fluorescenz und Phosphorescenz. Ann. Physik. Chem. **34**: 446–469. 1888.

Hyde, E. P., Talbot's law as applied to the rotating sectored disk. Bull. U. S. Bur. Standards **2**: 1–32. 1906.

Weber, A. L., Über die Anwendung des rotierenden Sektors zur photographischen Photometrie. Ann. Physik **45**: 801–838. 1914.

Pfund, A. H., cited in note 53.

Newcomer, H. S., The relation of the sector opening of the sector photometer to the extinction coefficient. Science (N. S.) **49**: 241–243. 1919.

summation of the actual amounts of light reaching it during the periods of illumination. This principle seems to be valid in photometrical work and the device has been of great value. Little is known of the applicability of the device to radiometry and actinometry although with some particular instruments it appears to yield reliable data.

Since photometry depends upon a standard light source it is of paramount importance that the standard chosen shall be exactly reproducible at any future time and shall be sufficiently constant in behavior during the period of each photometric observation. The standard sperm candle formerly used is much too variable in behavior (Coblentz states that an individual may vary 18 to 20%) and an exacting search has proceeded in the attempt to settle upon some standard that will meet the requirements with sufficient accuracy. The liquid and gas burning lamps are, as a rule, sensitive to prevailing conditions and are troublesome to operate so that the tendency seems to be toward the choice of incandescent electric lamps since for short periods direct current can be rather readily controlled. It may be possible to utilize an electric lamp with direct current controlled by some simple rheostat and operated similarly to an optical pyrometer for measuring radiation of high intensity in the visible spectrum. With appropriate color screens and dry cells the instrument might be very compact, convenient and have a great range of application.

By the use of a spectroscope and suitable accessories a spectrophotometer may be constructed by which the distribution of luminosity in the spectrum of the incident light may be obtained and from this an approximation to the relative distribution of energy.[43]

Recently the attempt has been made to measure light in terms of its luminosity without having recourse to the human

[43] Hartridge, H., An improved spectrophotometer. J. Physiol. **50**: 101–115. 1915.

Nutting, P. G., A pocket spectrophotometer. Bull. U. S. Bur. Standards **2**: 317–318. 1906.

Idem. A photometric attachment for spectroscopes. Bull. U. S. Bur. Standards **7**: 239–241. 1911.

eye as a receiver. This is termed physical photometry[44] and is accomplished by interposing between a radiometric instrument and the light source an absorption screen having a curve of transmissions for the various wave lengths similar to the curves of sensitiveness of the human eye. The measurements of the radiation received by the instrument are thus indicative of the effects upon an "average human eye" in the same position.

3. Actinometry

Because some chemical reactions proceed so much more rapidly in light than in darkness and since the rate of such reactions is in general more rapid the greater the intensity of the illumination, they have been utilized for the measurement of radiation. The elaborate investigations of sunlight by Bunsen and Roscoe[45] by these means, the attempt to relate features of plant growth to sunlight by Wiesner's[46] measurements along the same lines, the simplicity of operation and the growing accessibility of photographic supplies have led to an extensive use of actinometry in various fields of biological research. Because of this popularity actinometry will be considered more in detail than the relative (or actual) value of the results so far obtained by its means would justify in a well balanced discussion.

The generalizations at the basis of actinometry are that the optical principles of radiation hold for those wave lengths affecting chemical reactions and that only those waves that are absorbed by the substances concerned can be chemically active.[47]

[44] Ives, H. E., Physical photometry. Trans. Illum. Eng. Soc. **10**: 101–112. 1915.

Coblentz, W. W., The physical photometer in theory and practice. J. Franklin Inst. **180**: 335–348. 1915; **181**: 233–241. 1916.

[45] Bunsen, R. W., and H. Roscoe, Photochemische Untersuchungen. Ann. Physik Chem. **96**: 373–394; **100**: 43–88; 481–516; **101**: 235–263; **108**: 193–273; **117**: 529–562. Ostwald's Klassiker Nos. 34 and 38.

[46] Wiesner, J., Photometrischen Untersuchungen auf Pflanzen-physiologische Gebiete. Sitz. Math.-Nat. Cl. Kgl. Akad. Wien **102**, Abth. **1**: 291–350. 1893.

[47] Grotthus, T. von, Ueber die chemische Wirksamkeit des Lichtes und der Elecktricität. Jahresverhl. kurländ. Ges. Lit. u. Kunst. **1**: 119–189. 1819. Ostwald's Klassiker No. 152.

Regarding the first part of this statement, it may be noted that no general distinction can be made between waves that influence chemical reactions and those that do not. In fact, as photo-chemical investigation is extended the conviction grows that there is no portion of the spectrum (not excepting even the very long infra-red waves) that can be definitely said to be without effect upon some chemical reaction.

The second part of the statement is often misstated to the effect that those waves that are absorbed are chemically active. There is, however, no simple relation between absorption and chemical action. There are many cases known of strong absorption accompanied by no detectible chemical action and other cases in which there is marked chemical action and only slight absorption. This diversity occurs because the radiation effect is not always solely because of the addition of energy to the system, although of course the contribution of energy is all that the light makes, and among other effects there are those that for want of a better term are called catalytic.[48] It must be further noted that even in those cases in which the absorption and the speed of reaction are definitely and simply related the reaction does not proceed strongly in a limited portion of the spectrum, immediately bounded by regions of no activity. Instead, there is a more or less gradual increase in the effectiveness of the waves up to a maximum and a similar decrease beyond. Thus, while there is the possibility of obtaining measurements that may be interpreted in terms of energy transmitted in any desired portion of the entire spectrum by the proper choice of a chemical reaction with which to record it, it does not follow that the interpretation will be either exact or easy.

One class of photo-chemical reactions are, within certain ill-defined limits, of considerable usefulness for actinometric use. These reactions depend for their rate upon the intensity of the radiant energy absorbed and are accordingly rather precise means for obtaining relative measures of its intensity.

[48] Lewis, W. C. McC., Phys. Chem., vol. 2, 1914, p. 1.
Sheppard, S. E., Photo-chemistry. London, 1914.

The darkening of the silver halides, silver chloride and silver bromide, upon exposure to light has been extensively investigated and the rate of darkening has been found to vary, for one and the same light source, within certain limits, proportionally to the product of the intensity of the active radiation and the length of the time of exposure. This is the so-called "reciprocity law."[49] Since, however, the degree of darkening is difficult to determine, recourse is usually had to Bunsen and Roscoe's method of determining the time necessary to produce a definite degree of darkening, determined by comparison with an unfading standard tint placed immediately beside the darkening paper. From the reciprocity law it follows that the intensity of the effective radiation is inversely proportional to the time necessary for this fixed degree of darkening.

This darkening is usually said to be accomplished by the reduction of the silver salt to a sub-salt and the liberation of the free halogen (Cl or Br). If the light is removed the reaction will reverse and the original salt will be formed. Since the formation of the sub-salt is constantly opposed by the tendency of the halogen to recombine with it, the speed of darkening decreases with increasing time. This may be avoided to a large extent by adding another substance, such as gelatine or albumin, with which the free halogen may combine, thus maintaining the speed of reaction and, if the amount of this added substance is sufficiently great in proportion to that of the silver, the decrease in rate will be negligible. This reaction was first worked out by Luther[50] and may be written:

$$2\ AgCl + \text{gelatine} + \text{light} = Ag_2Cl + \text{chlorinated gelatine.}$$

Although the reciprocity law holds very exactly for a considerable range of intensity of monochromatic light (or light from sources whose energy distribution curves are the same shape) in the case of silver-chloride-gelatine preparations that are viewed directly, it does not remain in its simple form in the

[49] Bunsen, R. W., and H. Roscoe, Photochemische Untersuchungen. VI. Meteorologische Lichtmessungen. Ann. Physik Chem. **117:** 529–562. 1862.

[50] Luther, R., Studien über umkehrbare photochemische Prozesse. Zeit. Phys. Chem. **30:** 628–680. 1899.

case of preparations that are "developed" before the degree of darkening is judged. In this latter case (as with "plates") the relation becomes exponential and is termed Schwarzschild's rule.[1] It must be remembered that these expressions are only approximations to an unknown law and do *not* hold for very high or very low intensities.

Since silver-chloride-gelatine reactions, in common with other photochemical reactions, vary in their rate when exposed to radiation of different wave lengths it is obvious that unless the energy curve of the incident radiation is of the same form in all cases for which it is desired to measure the intensity, the rate of reaction alone will tell nothing about the intensity of the entire beam of light. Line A in figure 5 represents the curve of sensitivity of a silver-chloride-gelatine preparation (of course it is not the curve for *any* such preparation) to radiation at different wave lengths. The ordinates accordingly represent degrees of darkening in equal times when the intensity of radiation in any wave length is equal to that at any other.

If we imagine a beam of radiation to be incident upon this silver-chloride-gelatine actinometer and to be of equal intensity in all wave lengths between about 0.29 μ and about 0.53 μ (the approximate limits of sensitivity of the instrument) it will be at once apparent that the relative effects of the various kinds of waves in darkening the paper per unit of time will be proportional to the heights of the ordinates of curve A. Accordingly the *total* darkening of the paper in unit time by such a beam will be proportional to the area enclosed between the curve A and the base line. The darkening by such a beam at any effective portion of the spectrum smaller than the entire effective portion will be proportional to the area enclosed between the base line and the curve A between the ordinates erected at the wave lengths bounding the portion of the spectrum considered.

[1] Schwarzschild, K., Ueber Abweichungen vom Reciprocitätsgesetz für Bromsilbergelatine. Photographische Correspondenz. **36**: 109–112. 1899.

Renwick, F. F., Some deductions from Schwarzschild's rule. Phot. J. **56**: 11–13. 1916.

Draper, J. W., On some analogies between the phenomena of the chemical [illegible] Phil. Mag. (3) **19**: 195–210. 1841

or the *percentages* of the total darkening produced by this small portion of the spectrum will be equal to the quotient obtained by dividing the small area by the entire area first mentioned.

If, as is usally the case, the incident radiation is not of equal intensity at the various wave lengths, the graph of radiant

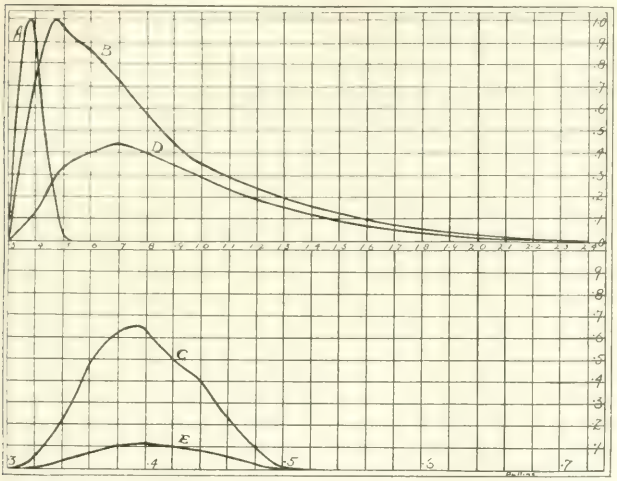

Fig. 5. Graphs exhibiting the effects of solar radiation upon silver-chloride-gelatine preparations. Line *A:* graph of sensitivity of a silver-chloride-gelatine preparation. Line *B:* graph of solar radiation; sun at 90° altitude. Line *C:* graph of effect of radiation represented by line *B* upon the photo-sensitive preparation. Line *D:* graph of solar radiation; sun at 15° altitude. Line *E:* graph of effect of radiation represented by line *D* upon the photo-sensitive preparation.

energy will also be a curve, and the resultant darkening will depend upon the overlapping portions of *both* curves. Line *B* in figure 5 represents an energy curve of solar radiation received at sea level with zenith sun. The maximum ordinate is expressed as unity so that all other ordinates are fractions of this maximum. Similarly the maximum ordinate of the sen-

sitivity curve is expressed as unity and all its other ordinates are likewise fractions.

If the two maxima coincided in postion on the scale of abscissas, unit darkening would be produced in unit time by the action of this maximally effective wave length when acting by itself. If the maximum sensitivity corresponds in position with a wave length of half the efficiency of the maximum, the degree of darkening in unit time will be one-half the maximum unity noted above; or if the maximum efficiency coincided in position with half the sensitivity the darkening would again be one half the maximum. In each case it is supposed that only those waves are acting whose ordinate values are considered.

The graph of the darkening produced in unit time by the radiation characterized by line *B* acting upon the paper having a curve of sensitivity, *A*, will accordingly be obtained by plotting the products of the ordinates of radiation and sensitivity at each wave length. The result is expressed in line *C* (plotted on a larger scale of abscissas). The total *amount* of darkening will be proportional to the area between line *C* and the base line, and if the darkening is to be a measure of solar energy, the areas enclosed by the curve of darkening and by the curve of radiation intensity must always bear a fixed relation to each other, since the former represents amount of darkening and the latter the amount of radiation incident upon the same surface in the same length of time. Of course only the radiation to which the paper is sensitive can be effective so, unless the remaining radiation bears a fixed relation to the effective portion, darkening cannot be a measure of the total radiation incident in unit time.

To find if this relation exists for the sun's radiation it is only necessary to compare the areas below different solar radiation curves in the different portions considered. To make it more concrete still, a darkening curve for solar radiation with the sun 15° above the horizon at sea level (curve *D*) is plotted as line *E*. The area between line *E* and its base (curve of darkening for 15° sun) is 0.19 of that between line *C* and its base (curve of darkening for 90° sun), so that the total radiation in the two cases should be in the same ratio if the actinometric method is to be useful for their measurement.

The area between line *D* and its base (total radiation for 15° sun) is 0.58 of the area between curve *B* and its base (total radiation for 90° sun). Since this last ratio is more than three times the first one given it is plain that the darkening is no measure of the total radiation, as might have been predicted.

The area between line *D* and its base in the portion of *visible* radiation is 0.42 of that of the corresponding portion of the area below line *B*, so the actinometer reading is likewise no measure of the visible radiation; nearly 55% error.

The area between line *D* and its base in the *effective* portion of the spectrum is 0.23 of the corresponding area below line *B* so that the actinometer does not even measure this portion of the spectrum with any degree of accuracy; nearly 18% error.

All this merely emphasizes the usually unappreciated facts that the actinometer readings are *only* valid when the radiation is either monochromatic or invariable in its distribution of energy, and that sunlight does not fulfill these requirements. The illustration also indicates that if a sufficiently small portion of the spectrum were transmitted to the paper by an appropriate screen, this portion might be measured satisfactorily for many purposes although no conclusion could be reached regarding the energy transmitted in other portions of the sun's spectrum.

To complicate the case still further a very large share of the ultra-violet radiation of wave lengths shorter than about 0.4 μ reaching the earth comes from the sky and, as will be seen from the sensitivity curve in figure 5, these waves are the most effective in darkening silver chloride. Furthermore, when the sun is close to the horizon, the sky is more effective than the direct beam so that if the actinomter is to measure either sky light or sun light is must be protected from radiation from the other.

There are of course other types of actinometers besides those depending upon the darkening of silver chloride paper. Photosensitive preparations that must be chemically treated after exposure to render the image visible ("plates" are examples) have been used and while the simple reciprocity law is not applicable to their action, Schwarzschild's rule is said to be,

although as a matter of fact it is well known that it is only valid for a relatively short range of intensities. Such preparations may be "sensitized"[2] for almost any portion of the spectrum, even including the shorter of the infra-red waves, while the "non-developed" papers cannot be thus sensitized in any way now known. It must not be forgotten that these sensitized preparations also exhibit curves and not bands of sensitivity and some of the curves have more than one maximum. Because such sensitized plates cannot be exposed until a certain amount of darkening results, their use is attended with considerable difficulties through the uncertainty in the comparison of the developed plate with standard tints.

Photo-sensitive reactions that occur in solution or in the gaseous condition have been utilized as actinometers but their use is attended by all the uncertainties encountered in the use of silver-chloride-gelatine papers and does not have the offsetting advantage of simplicity, for the solution or gas must be chemically analyzed by more or less convenient means to determine the extent to which the reaction has proceeded. A number of these have been proposed but since their curves of wave length sensitivity and behavior under different conditions of radiation intensity are not known, they are at present useless.

Of the remaining actinometric devices the photo-electric cell may be noted as a valuable instrument when properly constructed and in competent hands. The selenium cell has been suggested but Pfund[3] has found that the position of the maximum sensitivity varies with the intensity of the incident light so that it appears unpromising.

The alkali photo-electric cells, such as have been developed by Elster and Geitel have presented serious difficulties, which are, however, being overcome as their principles become better understood. Cells with high vacua or containing helium or

[2] See files and current numbers of The British Journal of Photography, The Photographic Journal; Zeitschrift für wissenschaftliche Photographie, Photophysik und Photochemie.

[3] Pfund, A. H., Application of the selenium cell to photometry. Phys. Rev. 34: 370-380. 1912.

argon are much to be preferred to those containing reactive gases because the ionization in the latter type upon exposure to intense radiation produces marked irregularities of behavior.[54] Like all instruments in the actinometric class they exhibit a curve of sensitivity and this curve must be known or the results obtained from their use in different portions of the spectrum are meaningless. Moreover, it is at present impossible to consciously prepare two cells even approximately alike in short or long wave limit of sensitiveness, or in spectral position or degree of maximum sensitiveness, so that the curve of sensitivity must be known for each individual cell.[55] To further complicate the problems connected with their use it has been found that their curves change with age of the cell so that the curve of sensitivity must be investigated at sufficiently short intervals.[56] The rate of change of these curves depends to some extent upon the degree of evacuation of the cells, full gas cells changing more rapidly than those with high vacua. Because the photo-electric effect occurs at the surface of the metal, advances in methods for preparing these surfaces should be attended by greater uniformity of cells; at present surfaces very carefully prepared at the same time and from the same materials yet show decided differences in behavior, although with proper standardization this objection is not serious. If the cells are properly constructed, the photo-electric current appears to be directly proportional to the intensity of radiation.[57]

Elster, J., und H. Geitel, Über eine notwendige Vorsichtsmassregel bei der Photometrie sehr grosser Lichtstärken vermittels hochempfindlicher Alkalimetallzellen. Physik. Zeit. **15**: 610–611. 1914.

Ives, H. E., Wave length sensibility curves of potassium photo-electric cells. Astrophys. J. **40**: 182–186. 1914.

Compton, K. T., and O. W. Richardson, The photoelectric effect II. Phil. Mag. (6) **26**: 549–567. 1913.

Kunz, J., The law of photoelectric photometry. Astrophys. J. **45**: 69–88. 1917.

Coblentz, W. W., Instruments and methods of radiometry III. The photoelectric cell and other selective radiometers. U. S. Bur. Standards Sci. paper 319. 1919.

Ives, H. E., The variation with time of the characteristics of a potassium photo-electric cell as to sensibility according to wave length. Astrophys. J. **46**: 241–248. 1917.

and although the instruments cannot be said to be well enough understood for general biological use, their value for some forms of laboratory work is undoubted.

Photo-voltaic cells and photo-electrolytic cells are of unknown value.

In conclusion a word may be said regarding means for transmitting only portions of the spectrum to radiation-sensitive instruments: dispersion and differential transmission.

Dispersion is accomplished by refracting the radiation by a prism or by reflecting it from, or passing it through, a grating.[5] As has been pointed out, in a prismatic spectrum the original intensity has been unequally altered by passage through a prism. This *deviation* effect may be corrected by using a train of prisms, the secondaries correcting the deviation while still allowing dispersion, so that the "direct vision" spectroscope yields a normal spectrum. There are many objections to these spectroscopes and the simplest and, in general, most reliable means of dispersion is the single prism. The data obtained with such a prism are easily corrected for deviation to yield results such as would have been obtained if a normal spectrum had actually been obtained in the first place. Gratings reduce the intensity of radiation more than do prisms because they yield many spectra and because of losses by extinction; they are expensive to rule and have had little use except in very precise work of certain kinds.

Isolation of portions of a spectrum by absorption of the remaining radiation may be accomplished by interposing suitable screens, either solid or liquid, between the instrument and the light source.[6] The solid screens may be thin layers of some absorbent element or compound, as a thin layer of gold for preventing transmission of infra-red radiation. Colored glasses are frequently used for the same purpose. It must be remembered, however, that the color of a screen is no insurance that it transmits only radiation between the wave length limits of that color.

[5] See, for example, Meggers, C. E. K., Light filters for photometry. Trans. Illum. Eng. Soc. 9: 900–905. 1914.

[6] Lyon, H. L., Artificial daylight. J. Franklin Inst. 177: 471–499. 1914.

Practically all glasses, regardless of their color are very transparent to infra-red radiation. That the transmission curve sinks in the red portion of the visible spectrum is no guarantee that it will not rise again in the infra-red. Much the same statement applies to the ultra-violet; ordinary glass, even in moderately thick layers, transmits as far as wave length 0.35 μ or 0.34 μ, and this may be true for a glass giving very complete absorption in the blue.[59] Moreover a glass does not show high transmission in a certain portion of the spectrum with almost complete absorption in immediately adjacent portions. Instead, it exhibits a transmission *curve* that often is of much the same general appearance as the curves for darkening of silver chloride-gelatine preparations shown in figure 5, or the sensitivity curve in the same figure (although a transmission curve may show more than one maximum, even in the visible portion of the spectrum).

The ordinates of such a transmission curve alter with changing thickness of glass (as is true of any absorbing medium—Lambert's law, Beer's law), the function being exponential and not linear so that a given piece of glass does not absorb twice as much as a piece of the same glass half as thick. This law only holds for monochromatic radiation. Lambert's law to the effect that the percentage of radiation absorbed by a given medium of given thickness is the same for all intensities of the incident radiation is also true only for single wave lengths or small spectral regions. When the radiation is complex, as with sunlight, the result is the absorption curve mentioned above. This must be determined for each piece of glass because it is at present impossible to produce sheets of glass that are alike in their absorbing power. The losses due to reflection from the surfaces of the glass plate (it must be remembered that a single plate of glass has *two* surfaces and that the entering ray also suffers multiple reflection between them) are usually calculated from Fresnel's law.[1] Even if the simplest form of actinometer

[59] Ham, W. R., R. B. Fehr, and R. E. Bitner, The absorption of ultra-violet by various kinds of glass. Penn. State College Report 1914. Part I: 158–162. Published 1916.

is used (a piece of silver-chloride-gelatine paper exposed directly without a screen of any sort) reflection takes place at the surface and unless the radiation is always incident at right angles to the plane of the paper the effect of these reflections is difficult to compute and, since the paper is constantly changing in tint, it varies in its reflections of the radiation in the various wave lengths composing sunlight, the matter becoming still more complex with polarized sky radiation.

Recently colored glasses have been manufactured that show rather sharply delimited transmission bands in which the transmission curve rises very abruptly to a flat-topped maximum. As such glasses are available by which, either singly or in combination, narrow transmission bands can be obtained in almost any portion of the visible spectrum,[60] they are convenient for many sorts of spectro-radiometric work. Upon exposure to intense radiation the transmission may, however, drop 15 or 20% at some wave lengths (the effect is not uniform at all portions of the spectrum for any piece of colored glass) due to the absorption of heat.[61] Rises in temperature of less than 40°C., have very small effects for most of these glasses, however, and by interposing a piece of clear glass between the sun and the colored glass the rise in temperature will not be excessive.

Liquid solutions are much like glasses in their general properties but have the advantage that the user can himself more easily vary the amount of absorption by small increments or decrements than is the case for glasses. The degree of absorption depends upon the total amount of dissolved absorbing substance encountered by the beam (thus being altered by both

[illegible] Bur. Standards Bull. 11: 109–166. 1914.

[illegible] investigation of the transmission of various substances. U. S. Bur. Standards Sci. paper 325. 1919.

[illegible] Phys. Rev. 7: 194–202. 1916.

[illegible] J. Franklin Inst. 187: [illegible]. 1919.

changes in concentration and in thickness of the absorbing layer) and hence the transmission curve may be changed at will and be duplicated. Some solutions exhibit very abrupt maxima in small spectral regions—transmission bands—so that for most purposes the radiation passing through them may be regarded as monochromatic. Aniline dyes and their combinations offer excellent banded transmissions in almost all portions of the spectrum, but they alter in solution upon exposure to radiation and fade quite rapidly if the insolation is intense. Solutions of inorganic substances are usually stable and offer a considerable range of choice of rather sharply banded spectra.

It may be noted that if the surface is always exposed at right angles to the incident beam and the transmission is always limited to the same small portion of the spectrum by the same prism or screen properly placed with respect to the beam, the percentage of radiation actually effective may be determined for the entire system once for all by experimental means, without having recourse to involved calculations which become increasingly difficult to evaluate the greater the number of surfaces involved.

Watts, W. M., Index of spectra. Appendix (a, w). 2nd ed. Manchester, England, 1889.

Eckert, F., and R. Pummerer, Photographische Spektralphotometrie der Absorptionsspektren von Farbstoffen. Z. Phys. Chem. 87: 599-618. 1914.

Jones, H. C., and J. A. Anderson, The absorption spectra of solutions. Carnegie Inst. Wash. Pub. 110. 1909.

Jones, H. C., and W. W. Strong, A study of the absorption spectra of solutions of certain salts of potassium, cobalt, nickel, copper, chromium, erbium, praseodymium, neodymium and uranium as affected by chemical agents and by temperature. Carnegie Inst. Wash. Pub. 130. 1910.

Jones, H. C., and J. S. Guy, The absorption spectra of solutions as affected by temperature and by dilution: a quantitative study of absorption spectra by means of the radio-micrometer. Carnegie Inst. Wash. Pub. 190. 1913.

Wood's Optics cited in note 1.

CORRELATION OF WIND FLOW AND TEMPERATURE WITH EVAPORATION[1]

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Several years ago the United States Department of Agriculture inaugurated the study of evaporation rates under standardized conditions on an extensive scale. While a few stations existed prior to 1916, that year saw the establishment of what are known as Standard Class A Evaporation Stations across the continent from east to west, especially in the more arid western half of the country. On January 1, 1918, there were thirty of these stations on the continental United States, and one at San Juan, Porto Rico.

The stations are standardized as to exposure, size of pan, position of instruments, etc. The pan is 48 inches in diameter, 10 inches deep, and is kept with 7 or 8 inches of water, the level of which is measured accurately by a hook gage constructed to read to the thousandth of an inch. The data taken include maximum and minimum temperatures, precipitation, air movement and its prevailing direction, and evaporation.

Two of these stations were established in Kansas, one near the western edge of the state at Tribune, and one at the University of Kansas, Lawrence. The station at Lawrence was located on top of Mount Oread, the highland at the junction of the Wakarusa and Kaw river valleys, at an altitude a little over 1000 feet. The elevation is about 200 feet above the flood plain to the north, east, and south. The location as given in the description furnished to the Department of Agriculture is latitude 38° 57′ 35″, longitude 95° 14′ 55″.

[1] Contributions from the Botanical Laboratories of the University of Kentucky No. 2.

It was my privilege to have charge of the station at the University of Kansas during the first three seasons of its operation, and to give personal attention to the taking of data. The first official records were taken on August 7, 1916, just nine days earlier than the establishment of the station at Tribune. The first season comprised 98 observations, to November 13, at which time the danger of injury to the pan from freezing com-

TABLE 1

Evaporation, air flow, and temperature data

MONTH	EVAPORATION	AIR FLOW	TEMPERATURE
August, 1916*	8.245	4.25	79.19
September, 1916	7.761	4.62	67.17
October, 1916	5.128	5.03	56.25
November, 1916†	2.013	6.92	52.4
March, 1917	5.953	7.87	44.9
April, 1917	5.681	6.61	52.8
May, 1917	5.701	3.73	58.2
June, 1917	8.385	3.525	71.65
July, 1917	11.061	2.83	80.4
August, 1917	6.956	2.09	73.57
September, 1917	5.445	2.61	69.35
October, 1917	4.114	3.645	50.64
November, 1917	3.079	3.72	47.4
April, 1918	4.821	4.03	48.45
May, 1918	8.453	5.2	68.35
June, 1918	9.325	2.65	77.45
July, 1918	9.881	2.76	77.6
August, 1918	12.020	3.42	83.71

Evaporation in inches per month, air flow average miles per hour.

* Twenty-five days.

† Twelve days.

pelled us to close the station. The second season of observation began March 1, 1917, and continued without interruption to November 30; and the third season extended from April 1 to August 31, 1918. The total number of observations taken was 526, but two of them were defective, and have been discarded because ice interfered with the measurement of the water level on October 20, 1916. The two days involved in this difficulty have been omitted from consideration in the statistical study.

The accumulation of data under standardized conditions from many widely separated localities representing wide diversities of climate, should make possible the institution of comparative studies of climatic conditions in various sections of the country, and lay the foundations of a more scientific crop ecology. The best way of making comparisons is statistical analysis of the data. During the period since my connection with the Lawrence

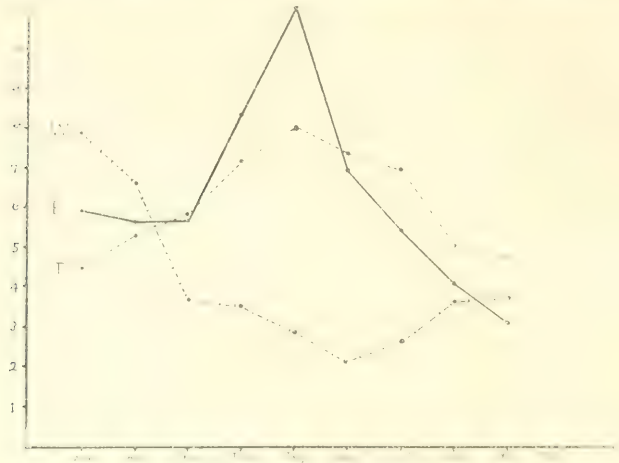

Fig. 1. Graphs showing the relation between the annual marches of evaporation in inches per month (*E*), wind flow in miles per hour (*W*), and temperature, divided by 10 (*T*).

station ceased, I have examined the data collected, and have subjected it to statistical treatment. Correlation tables showing the relation between wind flow and evaporation, and between temperature and evaporation are presented.

The seasonal curve of evaporation for the University of Kansas station is fairly normal, low early in the season, reaching a maximum in July or August, and falling off during the autumn months. The curve of average monthly temperature follows a

similar course, but the curve of surface wind flow shows that the early and late portions of the season are windier than midsummer. The data for monthly evaporation, average monthly temperature, and average hourly wind flow per month for all three seasons are shown in table 1, and the curves for the season of 1917 are shown in figure 1.

It seems obvious that the seasonal distribution of air flow is partly related to the development of vegetation. In the early

TABLE 2

[illegible]

Evap.	Air flow												
	100	50	200	150	200	250	300	350	400	450	500	750	1000 Freq. evap.
0.000–	16	43	14	6					1				80
0.100 –	35	65	32	10	4	3							149
0.200	44	55	23	9	7		2						140
0.300	17	38	21	9	8	2	3						98
0.400	3	12	9	3	6	1	1					1	36
0.500		1	2	8	2	1							15
0.600 –			1	1									2
0.700 –				1	2								3
0.800				1									1
[illegible]													
F. air flow..	115	214	102	48	30	7	6	1				1	524

months particularly, and in the autumn to a lesser degree, there is little obstruction to air flow from vegetation, but as summer advances this obstruction must offer considerable frictional resistance to atmospheric movement. At the same time convection currents are more vigorous in the early and late portions of the season, as these are the periods of rapid and violent temperature changes. It is also obvious from figure 1 that the correlation between evaporation and temperature is much closer than between evaporation and air flow. Unfortunately the

evaporation stations have not undertaken hygrometric measurements, so that this third important factor in evaporation rates, relative humidity, cannot be treated statistically.

The mean daily atmospheric movement for the 524 days of observation is 98.57 ± 1.99 miles, the mean daily temperature 65.06 ± 0.45 , and the mean daily evaporation 0.2376 ± 0.004. The correlation table for air flow and evaporation is shown in table 2.

TABLE 3

Correlation between temperature and evaporation

Daily evap.—	Average daily temperature→ 10	20	30	40	50	60	70	80	90	100	Freq. evap.
0.100—	1	2	19	35	9	8	6				80
0.200—		1	8	29	42	40	28	1			149
0.300—				6	28	36	54	16			140
0.400—				1	7	17	39	34			98
0.500—						2	11	21	2		36
0.600—						1	3	11			15
0.700—								1	1		2
0.800—									3		3
0.900—								1			1
Freq. temp	1	3	27	71	86	104	141	85	6		524

The standard deviation, σ, of wind flow is 67.7 ± 1.42 miles, and of evaporation, 0.1368 ± 0.0029 inch. By the usual methods of determining degree of correlation, it is found that the correlation coefficient for air movement and evaporation is 0.29 ± 0.027.

The distribution of evaporation with respect to temperature is shown in table 3.

The standard deviation of the temperature is 15.26 ± 0.32, and the coefficient of correlation is 0.687 ± 0.0156, which is a much closer correlation than in the case of air movement.

It must be understood, of course, that these coefficients apply only to open pan evaporation at this particular station, as it occurs under the standardized conditions fixed by the Department of Agriculture, and that the relation they have to evaporation from the soil or trees or other types of plants is still unknown.

Similar statistical studies of the data collected at the other evaporation stations, where topography, climate, and other factors might modify the coefficients to a certain extent, would be interesting. Such data would furnish a basis for comparison of climatic complexes, and would no doubt be of interest and value to ecologists generally.

BOOKS AND CURRENT LITERATURE

VEGETATION OF WASHINGTON AND IDAHO. A highly diversified area of about 4000 square miles in southeastern Washington and southwestern Idaho, drained by the Snake and Palouse Rivers, has been subjected to a very thorough ecological investigation by Weaver.[1] The several formations and associations are described in some detail and illustrated, but the most notable feature of the work is the excellent series of data on the critical physical conditions in the leading plant communities.

The western portion of the area is occupied by a desert scrub of *Artemisia* and *Chrysothamnus*. To the east of it are areas of xerophytic grassland dominated by *Agropyron spicatum* and less xerophytic grassland formed by *Festuca ovina*. The transition zone between the grassland and forest is occupied by a shrub community of *Symphoricarpos*, *Opulaster* and *Rosa*, which is sometimes improperly alluded to by the author as "chaparral." The pioneer member of the forest communities is *Pinus ponderosa*, closely followed by *Pseudotsuga*. The most important forests of the region are made up of *Larix occidentalis* and *Abies grandis*, and the climax is dominated by *Thuja plicata*.

The investigation of physical conditions has centred chiefly in the soil moisture and evaporation, which were determined at weekly intervals from May to September. Data are also given on soil temperature, air temperature, seasonal distribution of rainfall, and the chemical composition of the soil. There is an irregular rise in the rate of evaporation and a steady fall in the soil moisture during the rainless summer months. The graphs for these two conditions as determined in six of the leading plant communities show a progessive fall in evaporation rate and a rise in soil moisture as we pass from the *Agropyron* grassland, through the *Festuca* grassland, the *Opulaster* scrub, and the forests of *Pinus* and of *Pseudotsuga* to those of *Thuja*. In some cases the conditions for *Festuca* and *Pinus* are quite similar. Readings taken at depths of 2 and 10 in. indicate a progressive lowering of soil temperature as we pass from one community to the next in the successional sequence given

[1] Weaver, J. E. A Study of the Vegetation of Southeastern Washington and Northern Idaho. Univ. Neb. Studies 17: 1–144. figs. 18. Jan. 1917.

above. The soil moisture was determined for southwest and northeast slopes in the summer months. In the latter the percentage of moisture was from 50 to 100% greater than in the former during May and June, and from 20 to 50% greater during July, August and September. The determination of soil moisture at progressive depths down to 5 feet showed an increasing amount of moisture in July and August and a decreasing amount in December and April.

A preliminary paper by Weaver giving some of the earlier results of this investigation may be found in this journal,[2] with some data on the physical conditions which have not been republished in the paper under notice.—FORREST SHREVE.

A NEW BOTANICAL TEXTBOOK.—One of the latest additions to botanical literature is a textbook for agricultural students covering a year's work in botany.[1] The author's objects as stated in the introduction, are to present the structures and functions of flowering plants and to relate them to such agricultural subjects as farm crops, forestry and horticulture, and to the more advanced courses in botany; to present the kinds of plants with emphasis upon their evolutionary relationships and their economic importance; and to present evolution, heredity and plant breeding as related to the improvement of plants. Part 1 consists of chapters on flowers, pistils and stamens, seeds and fruits, germination of seeds, cells and tissues, roots, stems, buds and leaves; Part 2, chapters on thallophytes, bryophytes, pteridophytes, spermatophytes, classification of angiosperms and families of economic importance, ecological classification of plants, evolution, heredity and plant breeding.

In the opinion of the writer the arrangement of the chapters might easily be improved. Part 1 dealing with complicated structures should be much more readily grasped by the average student after completing the study of the lower groups of plants presented in Part 2. The chapters on cells and tissues, roots stems, buds and leaves should precede the study of the flower. Of course such readjustments are easily made. The addition of some ecological facts is commendable, and this feature of the book might have been added to in view of its importance to students of grazing and forestry. The volume contains much new information, the material is clearly presented and well illustrated, and it is a valuable addition to the list of college agricultural texts.—J. G. BROWN.

[2] Weaver, J. E. Evaporation and Plant Succession in Southeastern Washington and Adjacent Idaho. Plant World, **17**: 273–294, Oct. 1914.

[1] Martin, John N. Botany for Agricultural Students. John Wiley & Sons. 1914.

NOTES AND COMMENT

To everyone who has reflected upon the profound importance of paper in the maintenance of our modern civilization there will be matter of interest in the report made by Franklin H. Smith, Statistician of the Forest Service, on the production of wood pulp in 1918. During that year 5,251,000 cords of wood were converted into 3,319,000 tons of pulp in the United States. This production represents a decrease of 6%, from the preceding year, at the same time that our imports of wood pulp fell from 605,000 to 516,000 tons, and our exports of news print paper increased 5%, and some other classes of paper as much as 14%. In these war time figures lies a large part of the explanation of the recent shortage of paper and consequent increase in the subscription price of most newspapers and journals. In 1918 over 75% of the wood used for pulp was domestic or imported spruce, hemlock, and balsam fir, the heaviest cuttings of these trees being made in Maine, New York, Wisconsin, Pennsylvania and New Hampshire. In view of the growing shortage of hardwood lumber it is interesting to note that inroads are now being made on such trees as maple, beech, birch, and chestnut for wood pulp, although they form only about 4% of the total amount of wood consumed. The soda and sulphate processes are used for the reduction of hardwoods, while the sulphite and mechanical method are used for the conifers.

The incredible view that certain evergreen plants possess "starch leaves" and "fat leaves" has been refuted by Miss Gwynethe M. Tuttle for several herbaceous plants of western Canada (Annals of Botany, April, 1919). In late October the leaves were found to be poor in starch and rich in fats and oils. When potted plants of *Linnaea* and *Pyrola* and shoots of *Picea* were subjected to a temperature of 68° F. in the dark there was a reappearance of starch and a disappearance of the fats and oils. The epidermal cells of *Linnaea* are without starch during the summer, but filled with globules of oil in the autumn. In from two to eight days at the higher temperature the epidermal cells were found to contain a large amount of starch. The presence of lipase was demonstrated in the material. No evidence was found to indicate

that there is any difference between the various leaves of the same plant with respect to the presence of starch or fats under the same conditions. A sudden lowering of the temperature was found to kill plants of *Linnaea* in which the reappearance of starch had been experimentally induced.

A valuable place in bibliographical literature is being filled by the Agricultural Index (published by the H. W. Wilson Company, 958 University Avenue, New York). The Index is now in its fourth volume and is devoted to the publication of all titles in 77 of the leading journals in agriculture and related subjects. The titles are arranged topically and geographically, and are without abstracts. Both technical and popular material is included.

A Flora of the District of Columbia and Vicinity has been published as a Contribution from the National Herbarium by A. S. Hitchcock and Paul C. Standley, with the collaboration of a number of Washington botanists. In order to make the flora of more general use the technical key to families has been supplemented by a separate key based chiefly on vegetative characters. Some of the attractive scenery and showy plants of the Washington region are illustrated.

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WATER CONTENT AND TEMPERATURE AS FACTORS INFLUENCING DIASTASE FORMATION IN THE BARLEY GRAIN

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1. INTRODUCTION

The hydrolysis of starch-paste by germinating barley was observed by Kirchoff in 1814. The first account of an enzyme in solution is that of Dubrunfaut (1830). He found that an aqueous extract of malt converted starch-paste to sugar. The active agent for this conversion was not discovered until 1833. In that year Payen and Persoz (1833) precipitated by means of alcohol, from an aqueous extract of malt, a white powder which had the power of converting starch paste to sugar. This powder they called diastase. Since its discovery our knowledge of diastase has greatly increased. Its formation, distribution, and behavior to temperature, chemical agents, etc., have been the subject of especial investigations, and excellent discussions of the literature may be found in Green (1901), Effront (1902) and Czapek (1913).

Comparatively little is known concerning the relative activity of diastase, its increase or its decrease, in the resting seed under different conditions of moisture, temperature, etc., in storage. Since the quantity of water in the seed varies considerably under different conditions of storage and relatively small variations have a marked effect on fundamental life processes, as for example, respiration, it was thought worth while to investigate the effects of moisture and temperature on the grain in storage. White (1909) in studying the latent life of resting seeds, found that active diastase is present in them in an appreciable amount. The diastase and other enzymes

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retain their activity without appreciable change in stored dry seeds for 20 or more years, that is long after the power of germination has been lost, which takes place in wheat after 11 to 16 years, barley 8 to 10 years, oats 5 to 9 years, maize and rye over 5 years. The life of the stored seeds is largely dependent upon the climatic conditions, a dry climate favoring longevity.

The experiments of Kolkwitz (1901) on the respiration of barley as affected by moisture content are of interest, since it is through the hydrolization of starch by diastase that active and long continued respiration depends. Kolkwitz found that 1 kilo of barley with a moisture content of 10 to 11% gives off in 24 hours from $\frac{1}{3}$ to 1.5 mgm. of CO_2. In barley containing 20% water the respiration is markedly higher than could be attained through any increase of temperature in air-dry barley, that is, barley containing 10 to 11% water. One kilo of barley of 33% water content gives off in 24 hours 2000 mgm. of CO_2, and this quantity of CO_2 may be increased ten fold by an increase in temperature and an increase in the quantity of oxygen supplied. Duvel (1904), Babcock (1912), and others have had similar results.

2. MATERIALS AND METHODS

Water content and temperature are the two factors, the effect of which on the diastase content of the resting seed it was planned to study. Both factors must be controllable within narrow limits over considerable periods of time. Much time was used in working out methods by which the temperature and more especially the moisture content was maintained through longer periods of time and with relatively slight variations. Kolkwitz (1901) experienced a similar difficulty. He says,

> Die Hauptschwierigkeit dieser Untersuchungen lag in der Wahl einer geeigneten Methode, denn ein Schwanken im Feuchtigkeitgehalt der hygroskopischen Korner wahrend des Versuches hatte die Genauigkeit der Resultate ernstlich in Frage gestellt.

Manshury barley obtained from Vaughan's Seed Store, Chicago, was first used. It was given up and White Hulless sub-

stituted because it was found impossible to distinguish between the moisture held in the outer covering of the kernel and that of the kernel proper. Brown (1909) experienced a similar difficulty. He says,

> It should be pointed out that the determinations on which the curves are based are affected by an unavoidable error due to the manner in which the values are arrived at. Some allowance should be made for the amount of water absorbed by the outer covering of the seeds. It is not possible to evaluate this amount very closely; apparently, however, it may be taken as equal to about 8% of the original weight of the dry seeds.

An error of 8% in moisture content is far too large, since the respiration, as we have already seen, is markedly affected by far smaller moisture variations. We shall see later that this is also true of diastase activity in the seed.

Moisture control

Two methods, both successful, were used to bring the barley grains to the desired moisture content. The first, which might be termed the immersion method, was used when a relatively high water content was desired and the period of experimentation did not exceed 12 hours. The second, which might be termed the vapor tension method, was used in the greater number of experiments. It permits of a far more delicate control of moisture content and the desired content, once reached, can be maintained, under proper conditions, almost indefinitely. It cannot be used where a moisture content sufficiently high for germination, or nearly so, is desired.

The immersion method

Brown (1909) first called attention to the fact that the membranes covering the barley grain are semi-permeable in nature. In consequence of this and the strong affinity for water of the grain itself, it is possible by varying the density of the solution to furnish the grain a definite quantity of water. Schroeder

(1911) and Shull (1913) have applied and extended this method.

A definite quantity of barley grains was placed directly into a saturated solution of LiCl. This, according to Shull (1913), gives the highest osmotic pressure of any known neutral salt and he found that the seeds of *Xanthium* were unable to take up water from a saturated solution. This means that the osmotic pressure of the salt—965.3 atmospheres—is greater than the force of imbibition of the seeds. In solutions of less density it was possible for the seeds of *Xanthium* to take up water until the imbibition force of the seeds and the osmotic power of the solution were in equilibrium. Brown (1909) had found that the coats of the barley grain are semipermeable and that seeds extracted water from solutions of H_2SO_4, $NaNO_3$, $CuSO_4$, etc. Tests showed that the coats of barley are impermeable to LiCl in solution and solutions of this salt were chosen in preference to the solutions used by Brown. Much to my surprise the barley grain took up considerable water from a saturated solution of LiCl thus showing it to possess an imbibition force much greater than that of *Xanthium*.

Twelve test tubes each with 10 cc. of a saturated solution of LiCl were heated in a water bath to 30°C. Into each tube 100 air-dry barley grains, the weight of which had been previously determined were placed. Each tube was stoppered with a perforated rubber stopper with a capillary tube to allow an equalization of pressure during the heating. The tubes were then immersed in the water bath, so that the upper end of the glass tube only projected above the water. An equal number of samples of barley grains were treated in a like manner except that distilled water was substituted for the salt solution. Tubes containing air-dry barley served as checks. At intervals of 2 hours, three tubes, one containing a sample in the salt solution, the second containing a sample in distilled water, and the third, containing the air-dry check, were removed from the bath. The grains were superficially dried and their weight again determined. They were then placed on wire nets and dried in a current of warm air.

The vapor tension method

The vapor tension above a salt solution of dilute concentration held at a constant temperature is definite and constant. It is possible by changing the temperature of a solution of given density to raise or lower the vapor tension above the solution. By changing the density of the solution and maintaining a constant temperature, it is possible to obtain a wide range in vapor tension.

Half-gallon fruit jars were used as containers in each case. The tops were supplied on the inside with a hook for suspending the wire containers described below. The jars were supplied with solutions as follows:

(1) 400 cc. saturated solution of $CaCl_2$. Twadell reading..... 75.7°
(2) 200 cc. saturated solution of $CaCl_2$ plus 200 cc. of distilled water. Twadell reading..... 40.0°
(3) 100 cc. saturated solution of $CaCl_2$ plus 300 cc. of distilled water. Twadell reading..... 20.5°
(4) 50 cc. saturated solution of $CaCl_2$ plus 350 cc. of distilled water. Twadell reading..... 9.0°
(5) 400 cc. of water. Twadell reading..... 1.1°

For literature regarding the derivation of Twadell readings see Martin (1915), Sadtler (1912) and Thorp (1917).

After the jars were sealed they were placed into large temperature cases for 24 hours before the wire containers containing the barley were placed into them. By this means, there was set up a series of jars whose moisture content varied from the lowest to the highest possible under the prevailing temperature. Five series were thus maintained at temperature as follows: 5°C., 10°C., 15°C., 20°C., and 25°C.

After the jars had remained in the cases a sufficient length of time for the solutions and the air above them to reach an equilibrium, the jars were furnished with the wire baskets containing 50 grams of barley each. The cylindrical baskets were made of wire netting of fine mesh and were suspended by a bail from a hook in the top of the jar. The lower end of these baskets was 5 cm. above the liquid. Each container was weighed several times a day until it attained a constant weight.

As soon as a container attained a constant weight, a weighed amount of barley grains was removed and rapidly dried. The drying in this case took place in a drier especially constructed for the purpose. By means of a blower, heated air was driven over wire pans which were arranged in tiers and covered with a large tubulated bell-jar. Grains with the largest quantity of water used in these experiments were thoroughly dried in 2 hours.

When the seeds had become thoroughly dried they were ground to a fine powder. Five-tenths of a gram of this ground material was taken from each sample and digested for an hour at 50°C. in 50 times its weight of distilled water. During the process of digestion, the mixture was thoroughly stirred at frequent intervals. The extract obtained was placed in a centrifuge and rapidly rotated for ten minutes in order to remove all suspended materials, especially starch grains. This treatment was found to be necessary, for the amount of starch in the ground material was sufficient to introduce a large error in the results.

The starch solution

A 0.2% solution of soluble starch was used in all of the determinations for diastase. This was prepared by dissolving an accurately weighed amount of Lintner's soluble starch in boiling distilled water. A fresh solution was made for each determination.

Diastase activity

The diastase activity (Abderhalden 1910), (Oppenheimer 1911) of the ground barley was determined by adding 4 cc. of the barley extract to 20 cc. of the starch solution. The mixture was placed in a 50 cc. flask which was then immersed in the bath until only a small part of the neck extended above the water. At intervals, 2 cc. of this solution were removed from the flask and added to an equal quantity of distilled water in a test tube. It was rapidly brought to boiling and allowed to cool to room temperature. Each tube was then tested with 3 drops of a 0.1

normal iodine solution, which had been standardized by titrating it against a solution of sodium thio-sulphate. The tube which gave no reaction for starch or any of the dextrines when the iodine was added, was selected as the one determining the end point of the conversion. The moisture content of the air-dry barley was ascertained and the diastase activity determined in a like manner.

Temperature control

In the course of experimentation, two different temperature controlling devices, a water bath with thermostatic control and a temperature case, were used. The former was used for experiments at 30°C. For lower temperatures than 30°C. this was impracticable and the cases with chilling devices were employed.

In order to keep the starch solution at an even temperature during its conversion by the diastase extract, another bath was set up and maintained at a temperature of 50°C.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The air-dry barley grain under the storage conditions of the laboratory contained 8.76% of water. At temperatures of 5, 10, 15, 20, and 25°C., the diastase of this grain as determined by the period required to hydrolyze a starch solution of given concentration, is 44 hours, 00 minutes; 44 hours, 00 minutes; 42 hours, 45 minutes; 42 hours, 15 minutes; and 41 hours, 15 minutes respectively. These results —table 1—express the temperature effect on diastase in barley with 8.76% of water. The quantity of diastase in the barley grain at the above temperatures varied only slightly during a period of from 2 to 3 weeks. At a temperature of 30°C. the initial diastase is slightly increased and this continued for the period of exposure —12 hours. The results are shown in table 2.

The results given in table 3 show quite clearly that the vapor tension method is well adapted for furnishing different amounts of water to samples of air-dry grain. At 5°C. the water content of barley grains suspended above solutions of different concen-

TABLE 1

Diastatic activity of air-dry barley grains (checks)

TEMPERATURE	WEIGHT OF GRAINS USED	WATER CONTENT OF GRAINS	TIME FOR CONVERSION OF STARCH SOLUTION	
deg. C.	*grams*	*grams*	*hours*	*minutes*
5	1.9383	8.76	44	00
10	1.3815	8.76	44	00
15	1.8657	8.76	42	45
20	1.9138	8.76	42	15
25	1.8614	8.76	41	15

TABLE 2

Diastatic activity of air-dry barley grains (checks) at 30°C.

TIME IN BATH	WEIGHT OF GRAINS USED	WATER CONTENT OF GRAIN	TIME FOR CONVERSION OF STARCH SOLUTION	
hours	*grams*	*grams*	*hours*	*minutes*
2	3.7211	8.76	43	30
4	3.8348	8.76	42	45
6	3.6263	8.76	41	45
8	3.9076	8.76	41	15
10	3.9549	8.76	40	30
12	3.7246	8.76	40	00

TABLE 3

Per cent of water in samples used for diastase determination

SOLUTION	5°C.	10°C.	15°C.	20°C.	25°C.
Saturated solution of $CaCl_2$	10.91	11.02	10.51	11.51	11.98
200 cc. saturated solution $CaCl_2$ plus 200 cc. distilled water	16.44	17.54	17.37	19.44	20.38
100 cc. saturated solution $CaCl_2$ plus 300 cc. distilled water	22.34	23.68	24.90	24.38	25.07
50 cc. saturated solution $CaCl_2$ plus 350 cc. distilled water	24.72	25.76	30.70	29.06	30.58
Distilled water	26.83	29.91	28.74	30.97	32.48

tration from distilled water to a saturated solution of $CaCl_2$, varied from 10.91 to 32.48%. Above a saturated solution of $CaCl_2$ (1:1), air-dry barley grains take up only 2.15% of water but when placed above a solution approximately half as dense, (1:1), they absorb 7.68%, or about 3.5 times the quantity. When the density of the solution is again reduced by mixing 1

part of a saturated solution of $CaCl_2$ with 3 parts of distilled water, (1-3), the amount of water taken up by the grains is almost double that taken up by grains placed above a solution of equal parts of distilled water and a saturated solution of $CaCl_2$. A further decrease in the density, (1-7), causes another increase in imbibition but in this instance it is only 2% more than in the last mentioned case. Grains suspended above distilled water show a concomitant increase in the amount of water taken up. In this case it is about 2% higher than in grains held above the greatest dilution of $CaCl_2$ used. The above method enables one to study the diastase of the barley grain at 5°C. with a water content of 10.91%, 16.44%, 22.34%, 24.72%, 26.83%, respectively.

At 10°C. above solutions of $CaCl_2$ of the same concentrations as used at 5°C. the grains again give us an ascending series in respect to the water content and differ from the first (5°C.) in that the content above respective solutions is slightly higher. For example, the increase above the saturated solution of $CaCl_2$ is 0.11%; that above the solutions, 1-1, 1-3, 1-7, and distilled water is, 1.1, 1.34, 1.04 and 3.08% respectively. The amount of water taken up by barley grains at 15°C., when suspended above the different solutions, increases as the density decreases but the increase does not take place as uniformly as at the previous temperatures. These irregularities are to be expected because of the nature of the salt used ($CaCl_2$) as already observed by Wullner (1860).

The amount of water taken up by the grains at 20°C. above the series of solutions, again assumes a regular increase as the density is decreased. The amount of water taken up above distilled water is about 8 times as great as that absorbed above a saturated solution of $CaCl_2$. The same progressive increase in the amounts of water taken up by the grains is also found when the solutions are maintained at a temperature of 25°C. In this case the amount of water which the grains take up when suspended above distilled water is about 7 times greater than that absorbed above a saturated solution of $CaCl_2$.

The rate of hydrolysis, as shown in table 4, shows that the method allows a study of the effects of temperature and water

content on the diastase in the dormant barley grain. The factors, temperature and water content, have been the repeated subjects of investigation on the respiration of barley grains. The results show a general uniformity in that a rise of temperature as well as a rise in water content markedly affects the respiration. As already stated, the experiments of Kolkwitz (1901)

TABLE 4

Determination of diastase activity. Average of 2 trials

SOLUTION	5°C.		10°C.		15°C.		20°C.		25°C.	
	hours	*minutes*	*hours*	*minutes*	*hours*	*minutes*	*hours*	*minutes*	*hours*	*minutes*
Saturated solution of $CaCl_2$	36	52	36	15	36	00	35	37	34	52
200 cc. saturated solution $CaCl_2$ plus 200 cc. distilled water	34	22	33	15	33	22	32	22	31	37
100 cc. saturated solution $CaCl_2$ plus 300 cc. distilled water	29	52	27	30	28	00	27	45	26	27
50 cc. saturated solution $CaCl_2$ plus 350 cc. distilled water	27	30	26	37	25	37	24	52	23	45
Distilled water	26	07	24	15	25	52	23	07	20	00

first acquainted us with the effect of increased water content of the barley grain on its respiratory activity. Other investigators have had similar results. Bailey and Gurjar (1918) have recently contributed an elaborate investigation on the relation between respiratory activity and water content of stored grain. Their results on the respiration of Haynes Bluestem (Minnesota 169) wheat is of especial interest and is reproduced below.

MOISTURE	CARBON DIOXIDE RESPIRED PER 24 HOURS FOR EACH 100 GRAMS OF DRY MATTER	MOISTURE	CARBON DIOXIDE RESPIRED PER 24 HOURS FOR EACH 100 GRAMS OF DRY MATTER
per cent	*mgm.*	*per cent*	*mgm.*
12.50	0.54	16.08	2.88
13.93	0.65	16.65	6.86
14.78	0.86	17.07	11.72
15.42	1.62		

The water content of the air-dry grains increased only slightly when suspended above a saturated solution of $CaCl_2$ at 5, 10, 15, 20, and 25°C. respectively. The total increase of water content in the range of temperatures used is 1.07%. Above a solution of half that density, an increase in temperature of 5°C. is sufficient to cause an increase in water content, (1.07%) equivalent to that obtained throughout the whole range of temperature (5°C. to 25°C.) above a saturated solution. In the range of temperatures used (5°C. to 25°C.) an increase of 4% in the water content was observed. Above the other concentrations of the salt solution an increase of 5°C. produces an increase of

TABLE 5

Comparison of the water content of grains immersed in a saturated solution of LiCl *at 30°C. with diastase activity*

TIME IN SOLUTION	WEIGHT BEFORE IMMERSION	WEIGHT AFTER IMMERSION	GAIN	TOTAL WATER IN GRAIN	TIME FOR CONVERSION OF STARCH SOLUTION	
hours	*grams*	*grams*	*grams*	*per cent*	*hours*	*minutes*
2	3.6127	4.1494	0.5367	23.61	7	40
4	3.8323	4.5624	0.7301	27.76	6	50
6	3.8154	4.6247	0.8093	29.97	6	15
8	3.7905	4.6949	0.9044	32.62	5	40
10	3.8152	4.7978	0.9826	34.51	5	05
12	3.8732	4.9131	1.0399	35.60	4	45

from 1 to 1.5% in the amount of water imbibed. When distilled water is used, the effect of the temperature is about the same as in the more dilute salt solutions; an increase of 5°C. producing an increase of from 1 to 1.5% in the water absorbed.

In column 5 of table 5 are given the amounts imbibed, in per cent, by barley grains immersed in a saturated solution of LiCl at 30°C. In this case it is the time factor and the approach to imbibitional equilibrium that produces the differences in water content. At the end of two hours the grains absorb 14.85% of water, that is, have a total water content of 23.61% — water content of air-dry grains, 8.76% plus 14.85% increase. The quantity of water taken up was unexpectedly large. The results obtained by Shull in his experiments with *Xanthium* show a much

lower imbibition force. The results obtained with barley indicate that the imbibitional force exerted by the barley grain, expressed in osmotic pressure, is far in excess of that of the seed of *Xanthium*. At the end of 4 hours the grains had taken up 19.07% of water, an increase of 5.22%. Each 2 hour increase in the time of immersion produces an increase in the amount of water taken up, but the increase gradually lessens as the imbibitional forces reach more nearly equilibrium. The gain of 5.22% of the two-hour period is not again reached.

The amount of water, expressed in per cent, taken up by barley grains immersed in distilled water at 30°C. is given in column 5 of table 6. At the end of 2 hours the grains had taken up

TABLE 6

Comparison of the water content of grains immersed in distilled water at 30°C. with diastase activity

TIME IN SOLUTION	WEIGHT BEFORE IMMERSION	WEIGHT AFTER IMMERSION	GAIN	TOTAL WATER IN GRAIN	TIME FOR CONVERSION OF STARCH SOLUTION	
hour	*grams*	*grams*	*grams*	*per cent*	*hours*	*minutes*
2	3.9897	4.8387	0.8490	30.03	6	45
4	3.8667	4.9947	1.1280	37.93	5	50
6	3.8447	5.1592	1.3145	42.94	4	50
8	3.8676	5.3742	1.5066	47.71	4	05
10	4.0085	5.7212	1.7127	51.48	3	15
12	4.0815	5.9692	1.8877	55.01	2	30

21.27% of water, an amount 1.3 times greater than that absorbed from a saturated solution of LiCl in the same length of time. At the end of 4 hours 29.17% of water had been absorbed, an amount 1.2 times greater than that at the end of 2 hours. Here again as the grains are immersed for a longer time the amount of increase is successively less until at the end of 12 hours (55.01%) it is only 3.53% more than at the end of 10 hours (51.48%). The decrease is not so rapid as in the case of a saturated solution of LiCl. Upon comparing the water content of the barley grains after having been immersed for 12 hours in a saturated solution of LiCl and distilled water respectively, it can be seen that they are to each other as 1 : 1.26. This method

of moisture control permits the grains to take up a much larger quantity of water than was possible with the vapor tension method. The quantity of water taken up by the grains from a saturated solution of LiCl in 2 hours time is over 4 times that

TABLE 7

Comparison of the water content and diastase activity

TEMPERATURE			SATURATED SOLUTION OF $CaCl_2$		1-1		1-3		1-7		DISTILLED WATER	
5°	Percent of water		10.91g		16.44g		22.34g		24.72g		26.83g	
	Diastase activity	1st trial	*hrs.* 36	*min* 30	*hrs.* 34	*min* 45	*hrs.* 29	*min* 15	*hrs.* 27	*min* 15	*hrs.* 26	*min.* 30
		2d trial	37	15	34	00	30	30	27	45	25	45
		Average	36	52	34	22	29	52	27	30	26	07
10°	Per cent of water		11.02g		17.54g		23.68g		25.76g		29.91g	
	Diastase activity	1st trial	36	30	33	15	28	00	26	30	24	15
		2d trial	36	00	33	15	28	15	26	45	24	15
		Average	36	15	33	15	28	07	26	37	24	15
15°	Per cent of water		10.51g		17.37g		24.90g		30.70g		28.74g	
	Diastase activity	1st trial	36	00	33	00	28	15	26	00	25	30
		2d trial	36	00	33	45	27	45	25	15	26	15
		Average	36	00	33	22	28	00	25	37	25	52
20°	Per cent of water		11.51g		19.44g		24.38g		29.06g		30.97g	
	Diastase activity	1st trial	35	15	31	45	27	00	24	30	22	30
		2d trial	36	00	33	00	28	30	25	15	23	45
		Average	35	37	32	22	27	45	24	52	23	07
25°	Per cent of water		11.98g		20.38g		25.07g		30.58g		32.48g	
	Diastase activity	1st trial	34	15	32	15	27	00	24	00	19	45
		2d trial	35	30	31	00	26	15	23	30	20	15
		Average	34	52	31	37	26	27	23	45	20	00

taken up when suspended above a saturated solution of $CaCl_2$ maintained at a temperature of 25°C.

The results, table 7, clearly show that diastase formation in the barley grain is markedly affected by water content and by temperature.

At 5°C., a temperature a little above the minimum for diastase activity, a small increase in the water content of the grains shows a rather marked increase of the diastase. At this temperature grains containing 10.91% of water show a diastase activity of approximately 37, as indicated by the hours required to convert the starch in 20 cc. of a 0.2% solution. With a water content of 16.44% the diastase activity is $34\frac{1}{2}$. Thus (table 8), the water content of grains suspended above a saturated solution of $CaCl_2$ (5.45 grams) and that above a solution, 1–1, (8.22 grams), are as 5.45 : 8.22. The diastase of the same samples is as 36.8 : 54.3, expressed in the period of time necessary for conversion of the starch solution. Likewise the water content of grains above a solution, 1–3, (11.17 grams), and that above a solution, 1–1, (8.22 grams), are as 11.17 : 8.22, while the diastase of the same samples is as 29.8 : 34.3. In views of these facts and since a constant temperature was always maintained, it is evident that the water content of the grains is an important factor influencing diastase formation.

Similar comparisons may be drawn between the water content and the diastase formation at the other temperatures used. For example, at 10°C. as shown in table 7, the grains above a saturated solution of $CaCl_2$ contained 11.02% of water while those above distilled contained 29.91%, a difference of about 19%. The water content (table 8) in the first sample (5.51 grams) is to the water content in the second sample (14.95 grams) as 5.51 : 14.95, while the diastase in the two samples is as 36.25 : 24.25. While the per cent of water absorbed by the grains above the various solutions at 15°C. do not seem to conform to the amount absorbed at the other temperatures, from the results given in table 7, the diastase formation still seems to conform to the amount of water in the grains. Thus, while the grains contained more water when suspended over a solution, 1–7, than they did when held above distilled water, the time for conversion in the first case is about thirty minutes less than in the latter. In other words, the water content (table 8) of the first sample (15.35 grams) is to the water content of the second sample (14.37 grams) as 15.35 : 14.37. The diastase in these

samples is as 25.5 : 25.8. Likewise, table 7 shows that at 20°C. the diastase formation is dependent on the water content of the grains since in the samples an increase in the water of from 11.51% to 30.97% shows a concomitant decrease in the conversion time; that is, an increase in diastase formation. The water content of the grains suspended above a saturated solution (5.75 grams) is to the water content of the grains suspended above distilled water (15.48 grams) as 5.75 : 15.48. The diastase of the same samples is as 35.5 : 23.1. This is also true of samples maintained at a temperature of 25°C. (tables 7 and 8). In this instance the water content of the grains above a saturated

TABLE 8

Quantity of water present in grain used for diastase determination

SOLUTION	5°C.	10°C.	15°C.	20°C.	25°C.
	grams	*grams*	*grams*	*grams*	*grams*
Saturated solution of $CaCl_2$	5.45	5.51	5.25	5.75	5.99
200 cc. saturated solution $CaCl_2$ plus 200 cc. distilled water	8.22	8.77	8.68	9.72	10.19
100 cc. saturated solution $CaCl_2$ plus 300 cc. distilled water	11.17	11.85	12.45	12.19	12.53
50 cc. saturated solution $CaCl_2$ plus 350 cc. distilled water	12.36	12.88	15.35	14.53	15.29
Distilled water	13.41	14.95	14.37	15.48	16.24

solution of $CaCl_2$ (5.99 grams) is to the water content of the grains suspended above distilled water (16.24 grams) as 5.99 : 16.24. The diastase of these same samples is as 34.8 : 20.

Tables 5 and 6 give a comparison of the water content and of the diastase activity of grains at 30°C. Here, as in the previous experiments, the dependence of the diastase formation on the water content is clearly shown, as each increase in water content causes a concomitant decrease in the time necessary for conversion. Thus, the water content (table 9) of the grains after 2 hours (0.85 gram) is to the water content after 12 hours (1.37 grams) as 0.85 : 1.37. The diastase of the samples is as 7.6 : 4.75. There is also a marked difference between the diastase of the samples which have been immersed in a saturated solution of

LiCl and distilled water respectively, since the quantity of water in the former is to the latter as 1: 1.5.

While the water content at a given temperature markedly affects the diastase formation, it must be borne in mind that an increase in temperature toward the optimum of diastase formation likewise produces an effect. A closer study of the figures in tables 3, 8, and 4 show that a difference of 0.17% in the amount of water contained in the samples of grains suspended over the solution, 1-3, at temperatures of 15°C. and 25°C. respectively, causes a reduction of the time required for conversion of about $1\frac{1}{2}$ hours at the latter temperature. In other words the water content (12.45 grams), table 8, at 15°C. is to the water content

TABLE 9

Quantity of water present at 30°C. in grain used for diastase determination

TIME	SATURATED SOLUTION OF LiCl	DISTILLED WATER
hours	*grams*	*grams*
2	0.8531	1.1984
4	1.0657	1.4667
6	1.1435	1.6512
8	1.2364	1.8463
10	1.3168	2.0638
12	1.3791	2.2452

(12.53 grams) at 25°C. as 12.45 : 12.53. The diastase from the same samples is as 28 : 26.5. Likewise the water content (15.29 grams) above a solution, 1 7, at 25°C., is to the water content (14.95 grams) above distilled water at 10°C. as 15.29 : 14.95. The diastase from the same samples is as 23.75 : 24.25. Although the difference in the quantity of water contained in the sample of grains above distilled water at 5°C. and that contained in a sample above a solution, 1 3, at 25°C., is rather wide, the time required for conversion in both cases is approximately the same. That is, the water content (13.41 grams) in the first sample is to the water content (12.53 grams) in the second sample as 13.41 : 12.53 while the diastase from the same two samples is as 26 : 26. The results tend to show that temperature does have an effect on the diastase formation.

The samples of barley used in these experiments were random samples. All unsound or broken grains, however, were eliminated.

4. CONCLUSIONS

1. Absorption of water by the barley grains is dependent on the temperature.

2. The coats of the barley grain are impervious to LiCl for the period of experimentation.

3. The rate of absorption of water from a saturated solution of LiCl at 2-hour intervals decreases much more rapidly than from distilled water.

4. The osmotic pressure of the barley grain is much greater than that of *Xanthium* seeds.

5. The water content of barley grains after twelve hours immersion at 30°C. in a saturated solution of LiCl and distilled water respectively is as 1: 1.8.

6. When suspended over solutions varying from a saturated solution of $CaCl_2$ to distilled water, the amount of water absorbed increases in decreasing amounts, if the temperature remains constant.

7. At a constant temperature diastase formation increases with the water content of the grains.

8. Diastase formation in the barley grain is affected by temperature though not to so great an extent as by the moisture content of the grains.

9. After twelve hours at 30°C. the diastase of the barley grains in a saturated solution of LiCl and in distilled water respectively is as 1: 2.17 while the water content is as 1: 1.8.

I take pleasure at this time in acknowledging my indebtedness to Professor Charles F. Hottes, for the invaluable assistance he has given, both in the construction of apparatus and in the experimental procedure.

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THE EVIDENCE FOR A GROWTH-INHIBITING SUBSTANCE IN THE PEAR TREE[1]

H. S. REED AND F. F. HALMA

It is the purpose of this paper to call attention to the manner of development of new shoots on the cultivated pear tree and to discuss the evidence for a growth-inhibiting substance afforded by the phenomenon. The observations were made on a block of young Bartlett pear trees growing on the grounds of the Citrus Experiment Station.

Figures 1 and 2 show young branches of a Bartlett pear tree and the effect of heading them back. The points at which the original shoots were cut off are plainly seen. Figure 1, *A*, shows that two buds developed after the original shoot was amputated and that the shoot from the upper bud reached a size many times greater than that arising from the next lower bud. Figure 1, *B*, likewise shows that two subapical buds developed into shoots. The disparity in size is not so marked as in the former example, but it is nevertheless apparent. Figure 2 shows a vigorous shoot which was twice cut back. During the winter it was cut at *A* and in July of the following summer three of the new shoots were cut off at *B*. Following the first pruning, six vigorous shoots were produced from buds lying close to the point of amputation. The three upper shoots were plainly more vigorous than the three lower, though the distance between the buds from which they arose is not great. As a result of the July pruning, whorls of new branches were produced below the points of amputation in essential repetition of the previous development. Had the three upper shoots been unpruned they would have remained with few or no branches as did the three lower shoots. Emphasis must be laid on two features shown by these examples:

[1] Paper 59, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

(1) the young shoots remain unbranched for a long time if the apical bud remains active; (2) when a portion of a shoot is amputated, the buds immediately below the point of amputation are not only the first to develop into shoots, but they produce the largest shoots.

Fig. 1. The type of regeneration resulting from amputating young branches of the pear tree.

A. Two shoots very unequal in length which developed from two buds just back of the point of amputation. The lower shoot started much later than the upper.

B. Two shoots which started at the same time, yet the upper shoot is larger than the lower. The upper shoot produced one lateral late in the summer following the cessation of growth of the terminal bud.

So long as the apical bud of a shoot grows uninterruptedly, there is seldom any development of lateral branches, as is shown

by *A* in figure 1. If the apical bud is arrested in its development a neighboring lateral bud promptly develops and continues the growth, as shown in the upper shoot of *B* in figure 1.

The sequence of events in a regenerating shoot is so well known that further discussion is unnecessary. Many other trees produce new shoots in the same consistent manner as the pear tree. The cause for the regular basipetal development of shoots on a branch has not been clearly understood. The object of this discussion is to emphasize the inadequacy of our former ideas on the subject and to call attention to a more plausible explanation of the facts.

Among the statements current (but vague) there is an idea that the apical bud, or buds, secures the major portion of the sap in the branch and so develops at the expense of the sub-apical buds. Another statement which carries the same idea in somewhat more mystical language is to the effect that "shoot-forming substances rise in the plant while root-forming substances descend." If this concept be the correct one, it would seem that the basal buds should be the first to develop since they would first receive the "shoot-forming substance." But this is precisely what does not happen, as is shown by instances cited above.

To assume that "polarity" determines the course of events in the regenerating shoot is to render one's position somewhat more unassailable because of our ignorance of the nature of "polarity," but does little to elucidate the question. There is no basis in fact for comparing a living shoot with a magnet.

If we cast aside the older ideas and assume that a growth-inhibiting substance is produced in the apical region of the shoot which perpetuates a condition of dormancy in subapical buds, we shall find that we have a theory which fits the facts.

Loeb[2] has already shown that the presence of a growth-inhibiting substance would satisfactorily explain the course of events in the regeneration of *Bryophyllum calycinum*.

[2] Loeb, J. The chemical basis of axial polarity in regeneration. Science, n.s., **46**: 547, 1917.

Loeb, J. The law controlling the quantity and the rate of regeneration. Proc. Nat. Acad. Sci., **4**: 117–121, 1918.

The writers[3] have also shown that there is support for the idea that a growth-inhibiting substance exists in the shoots of the Chinese lemon which determines to a large extent the sequence of events in a regenerating shoot. It was shown that upright shoots remain unbranched, except for a few laterals near the apex. If the original shoot be fixed in a horizontal position, buds on the dorsal side will promptly develop; hence there must be something which perpetuates a condition of dormancy in the buds on the vertical shoot.

Some salient relations between the growth-inhibiting substance and the course of development were shown by the growth of new shoots on cuttings of the Chinese lemon. The results of these experiments gave strong support for the assumption that there is a substance produced in the apical region of the growing lemon shoot and that it travels through the phloem toward the basal region of the shoot. This substance seems to be the cause of dormancy in the subapical buds. According to this theory the apical buds on a cutting are the first to develop because they are the first to be freed from the inhibitory substance. As soon as the apical buds develop new shoots, they also produce the inhibiting material which migrates toward the basal buds and perpetuates the condition of dormancy.

It does not appear that the movement of the growth-inhibiting substance in a cutting is directed solely by the pull of gravity, because the progress of growth in an inverted vertical cutting is practically the same as in a cutting in normal vertical position.

Any bud on a cutting will develop if one removes a piece of bark and phloem immediately above the bud because the inhibiting material from the apical regions is thus prevented from reaching the bud.

The growth of sprouts on a potato tuber affords confirmatory evidence of the presence in them of a growth-inhibiting substance. Appleman[4] has shown that the buds on the apical end

[3] Reed, H. S., and Halma, F. F. On the existence of a growth-inhibiting substance in the Chinese lemon. Univ. of California, Publ. Agr. Sci., **4**: 99-112, 1919.

[4] Appleman, C. O. Physiological basis for the preparation of potatoes for seed. Bull. 212, Maryland Agr. Exp. Sta., 1918.

of the tuber first grow into sprouts and that they inhibit the growth of the more basal buds. If the tuber is cut into transverse slices, the inhibitory influence of the apical buds does not reach the others and there is a general development of buds over the entire tuber, depending upon the thickness of the slices.

If we consider the behavior of the pear branches previously described, we shall see that their behavior can be admirably explained upon the assumption that the growth of new shoots is regulated by the action of a growth-inhibiting substance produced in the apical portion of the branches.

In the light of this hypothesis, it is rational that the new shoots appear as they do. It is reasonable to assume that all lateral buds on shoots such as those shown in figure 1 are capable of growth, indeed we have found that if the inhibiting factors be removed each and every bud will develop into a shoot. We seem warranted in assuming, therefore, that growth will take place at each meristematic point unless restrained by some inhibiting factor.

In the case of pear shoots like those shown in figures 1 and 2, it would appear that the buds immediately below the point of amputation grow first because they are the first to be freed from the inhibiting substance. As soon as the new shoots began to grow, they began to produce more of the inhibiting substance which in turn kept the buds below them dormant. So long as the apical buds of the new shoots were uninterrupted in their development all buds beneath them remained dormant. The experiment on the branch shown in figure 2 is conclusive evidence that the non-development of the lateral buds was not due to immaturity, since when the three upper shoots were amputated, their stumps soon produced new shoots, while the two uncut shoots produced no corresponding growth. (The small spurs near their apices developed late in the season as the apical buds ceased their activity.)

In all the cases here presented the shoot from the uppermost bud from the bud nearest the point of amputation was the most vigorous produced from that particular stump and the size of shoots was regularly less as the distance from the point

of amputation was greater. In few cases is the disparity so great as in figure 1, A, where the second shoot started some time later than the first. The smaller size of the inferior shoots appears to be due to the effect of the growth-inhibiting substance produced in those above, an effect to which each shoot contributes, with the result that the lowest buds are entirely prevented from developing.

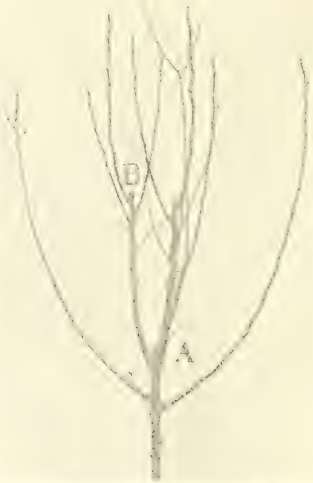


Fig. 2. Regeneration of shoots on a pear branch which was twice trimmed. In the winter the branch was cut at *A*, and in the following July the upper three shoots were cut off at *B*.

The discussion thus far has been based upon the phenomena of growth in upright shoots. It will be next in order to examine the behavior of shoots in horizontal position to see whether the above assumptions are confirmed or contradicted.

Figure 3 shows an instructive case. The branch there shown was originally vertical. The main axis, which grew slowly, rep-

resents three seasons' growth. The slow growth of the second season during which time the shoot was erect did not prevent the development of fruit spurs from *A* to *B* on the wood of the previous year. The weight of the branch in the second season plus the weight of fruits bent the main axis into an approximately horizontal position.

The growth which occurred in the third season was very characteristic. The growth of the previously formed spurs (between *A* and *B*) depended entirely upon their position. Those

Fig. 3. A pear branch which changed from the vertical to the horizontal position after fruit spurs from *A* to *B* had been produced. See text for explanation.

which lay close to the "dorsal line" of the branch developed into vigorous shoots (about 55 cm. each); those situated on or near the "lateral lines" of the branch grew less (5 to 20 cm. each); those situated on the "ventral line" of the branch scarcely grew at all in length (0.6 to 1.5 cm.).

The portion between *B* and *C*, which possessed no lateral shoots at the time the branch assumed a horizontal position, produced several shoots following the very slow growth at the apex. Here

again, buds on or near the dorsal line produced much larger shoots than those near the lateral lines. Buds situated on the ventral line were mainly dormant and those which did grow produced shoots less than 1 cm. long.

We may now proceed to analyze the growth phenomena of the branch in the light of our previous discussion.

The writers have previously shown that horizontally suspended cuttings of the Chinese lemon produce new shoots only from the dorsal side. The behavior seems to indicate that the inhibiting substance accumulates along the ventral side of a horizontal shoot.

If we assume that a similar condition exists in the pear tree branches, we shall have a logical explanation for what occurs. In a branch such as shown in figure 3, growth takes place vigorously from the dorsal side, because that region is freest from the growth-inhibiting substance; growth along the ventral line of the branch is almost totally inhibited because the growth-inhibiting substance is there most abundant. There is no reason whatever to assume that the buds on the ventral side of such a branch are in any way less capable of development than those on any other side. Had the branch been bent in the opposite direction, the type of growth would have been the same, though produced from buds on the opposite side of the branch.

If it were a question of the relative abundance of food substances, we should expect the opposite result, since it is difficult to see how the upper half of the branch could be filled without also filling the lower half.

It need not be assumed, however, that the movement of this hypothetical substance is wholly dependent upon the pull of gravity. It will be seen that in the basal portion of a horizontal branch the growth, even of dorsal shoots, is more and more restricted until finally buds are reached which are wholly dormant. It seems logical to assume that the inhibitory substances are principally carried in the basipetal stream of elaborated materials which travels in the phloem and are secondarily influenced by the pull of gravity.

This persistent tendency of artificially bent branches to produce shoots on the upperside, is well illustrated in espalier or horizontal cordon trees. Unless the dorsal shoots are promptly removed when still small, the horizontal arms will suffer and the shape of the tree will be spoiled. In changing the vertical shoot of such a tree to a horizontal arm, the bending has to be gradual because if done at one operation the ventral side of the arm will be bare; if done gradually the buds which will eventually be on the lower side have a chance to grow, and the spurs will form fruit buds before the arm finally assumes a horizontal position.

SUMMARY

1. Young vertical shoots of the pear tree tend to remain unbranched because of the dormancy of the lateral buds. Amputation of a portion of the shoot is followed by a development of lateral buds situated immediately back of the point of amputation.

2. The manner of growth affords evidence for the hypothesis that a growth-inhibiting substance is produced in the apical portion of the shoot and that it travels towards the base, perpetuating a condition of dormancy in the subapical buds.

3. Horizontal shoots of the pear tree produce the most vigorous growth from buds near the dorsal line of the shoot, little growth from those on the ventral line, and intermediate growth from those situated between the dorsal and ventral positions. This behavior indicates that the growth-inhibiting substance accumulates on the ventral side of such a shoot, thereby freeing the dorsal buds from the restraining factors.

BOOKS AND CURRENT LITERATURE

Science of Plant Life.—When a great modern corporation or business firm contemplates a new venture in their line of business, the situation is very carefully canvassed. Efficiency experts are set to work. They survey every angle of the venture, make reports and estimates. From this mass of data conclusions are drawn and plans made. But how about the writing of textbooks for high schools! How often do even the authors of textbooks of biological science approach the matter in a truly scientific fashion without bias? In the case of botany the author is usually a college professor. In his younger days he may have taught botany in a high school,—he may have taken some interest in high school botany. But he has been out of the schools for years, has become saturated with university methods and does not realize that he has lost touch with the high school situation. However he is always confident he knows just what is needed without investigation. What is a secondary school textbook for: to open up the world of science to the pupil in a manner the student can appreciate and understand, or to exploit an author's notions about secondary education?

The author of Science of Plant Life[1] expresses himself very frankly. He has certain beliefs about textbooks of botany and writes a book which embodies these beliefs. There is no evidence that these opinions are based on an educational survey of the teaching of botany in high schools or that the views of teachers in the work were obtained *before* the business of writing was undertaken. A concrete illustration of this method of approach to authorship may be taken from the preface. The author asks rhetorically, "Is it best to give a 'practical' turn to the course by inserting chapters from other subjects like agriculture, forestry, and plant breeding; or shall the course be kept within the strict confines of botany." . . . . The author's answer is indicated by the tone of the question and further by the fact that all the "practical" topics are missing from the table of contents. But the trend of botanical teaching in high schools is toward the inclusion of these practical topics as giving life and meaning to the principles of botany.

[1] Transeau, E. N., Science of Plant Life. Pp. 336, figs. 194. World Book Co., 1919. $1.48

There is no doubt that the biological subjects, botany and zoölogy, have been losing ground and that agriculture has been displacing them in the high schools. There has been a feeling in many places, evidently, that botany and zoölogy were not making good. Many biology teachers believe that there is need of a closer connection of these subjects with the "problems of every day" the animals and plants which help us to live and enjoy living. A well known university teacher expressed this idea in saying that the fundamental principles of botany can be learned as well from a study of the garden as from unfamiliar plants. "Practical" topics such as forestry, weeds, gardens and many others approached in this way do not detract from the subject as a science, and add much interest because familiar phenomena are explained.

Science of Plant Life as a textbook has many attractive features. The reviewer was much interested and very well pleased in his first impressions of the book. The thing that is most striking is the originality of the treatment of the subject matter of the seed plants. Topics like the "Environment of Plants" and others of like nature pertaining to the life of plants and the forces that influence them are used. But, strange to say, having gone this far with seed plants, there is a relapse, when the lower forms are taken up, into the usual series of studies. How the book will work in actual class use cannot be predicted with certainty, but a careful reading inclines us to believe that the style and vocabulary are too technical for tenth grade pupils and that they will have difficulty in reading and assimilating the subject matter. Most authors of biological textbooks find it impossible to put away habits of thought and speech used with fellow teachers and students for the simplicity of style and thought needed to make these subjects clear to young boys and girls with no such vocabulary or familiarity with science.

On the whole we feel that Science of Plant Life has failed to meet the real—we may almost say the desperate—need for a textbook of botany, which shall be up to date with the present situation in the high schools, in subject matter and method of approach, and presented in a manner simple enough to interest high school students. The book is worthy of consideration as the textbook situation now stands.—W. WHITNEY.

Root Tubercles.—Spratt[1] has investigated the structure of root tubercles in several legumes and non-legumes, among the latter, *Cycas*, *Podocarpus*, *Alnus* and *Ceanothus*. In all *Bacillus radicicola* enters through the root hairs. The origin of the nodule, however, is different in the two groups. In legumes, the infection is followed by hypertrophy of the cortex of the invaded root, which results in a mass of tissue becoming externally visible. At the base of this mass vascular elements appear which become continuous with the stele of the root and develop superficially in relation to the bacteria-containing cells. Eventually the tubercle breaks through the root parenchyma. Modification of the peripheral meristem of the tubercle often occurs, so that the surface may be rough or branched instead of smooth and roundish. In *Robinia*, *Sophora* and *Acacia*, the tubercles are perennial and develop from the phellogen a protective tissue.

In non-legumes, the nodule is a modified lateral root which becomes infected with *Bacillus radicicola* while traversing the cortical parenchyma of the parent root. Since the plerome of the lateral root is already differentiated the stele remains unaffected to continue its central position,—a position just the reverse of that occupied by the vascular strands in the nodules of legumes.

The cell sap is said to have a marked influence on the invading bacteria, determining the ability of the latter to enter and the extent to which infection threads may be produced.—J. G. Brown.

Penetration of Bean Cuticle by Colletotrichum Lindemuthianum.—That *Colletotrichum Lindemuthianum* penetrates the cuticle of the host in a purely mechanical way and is unable to gain entrance by disorganizing the cuticular layer, is claimed by Dey.[2] An appressorium is formed by the germ tube, which is attached to the surface of the host by a mucilaginous envelope. The appressorium subsequently sends out from its surface a peg-shaped infection hypha which pushes through the cuticle of the host in the same manner exhibited by *Botrytis cinerea*.—J. G. Brown.

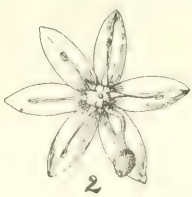
[1] Spratt, Ethel R. A Comparative Account of the Root-tubercles of the Leguminosae. Ann. Bot., **33**, pp. 189-200. 1919.

[2] Dey, P. K., Studies in the Physiology of Parasitism. Ann. Bot. **32**, pp. 305-312. 1918.

NOTES AND COMMENT

An aberrant inflorescence of *Allium mutabile* Michx. was collected by the writer on May 1, 1918, from a plant growing with many others along a railroad in the suburbs of the town of Arlington, Texas. In the two abnormal flowers found, were exhibited two unusual modifications: (a) Certain of the stamen primordia had developed flowers instead of stamens. These flowers were apparently normal except in being much smaller than the usual flowers; (b) In one of the two aberrant flowers the apparently normal ovary was surrounded (within the stamen cycle) by imbricated petaloid structures. Only two flowers, both belonging to the same inflorescence, were found, although an extended search was made on the other plants which were growing rather profusely in the neighborhood.

1



2

Figure 1 shows the condition in one of the flowers in which the greatest departure from the normal has taken place. It will be noted the perianth is asymmetric, one of the sepals having failed to develop. Also in addition to the "flower-like" stamens are two abortive filaments. Only two of the stamens of this flower are normal. At the center is seen the petaloid envelope surrounding the ovary. In figure 2 is shown the other flower in which but one stamen primordium had developed abnormally. The remainder of the flower is apparently normal in every respect. All of the small secondary flowers (most of them in bud condition near anthesis) possessed anthers borne on short filaments, which were of similar size to the anthers of the primary or normal flowers. Pollen grains from these anthers could not be distinguished from normal pollen grains. The pistil, however, was much reduced as compared

with the ordinary pistil, but bore a normal size relation with the perianth of the aberrant flower in which it had been developed. The common phenomenon of bulblet formation in the inflorescence of species of *Allium* presents a fundamentally similar problem. In the present case the interest lies in the fact that a stamen primordium is concerned and that merely a single flower is reproduced and not the entire plant, as in bulblet formation.

No theories are here offered in regard to the phenomenon. It might be suggested, however, that if such a case were a mutation it might give us a hint as to one method, at least, displayed in the evolution of the compound umbel. If this condition involved many of the flowers of an umbel and was accompanied by the disappearance of the pistil and the reduction of the perianth segments to bracts, it is evident that a compound umbel would result.—B. W. Wells.

The publishing house of Martinus Nijhoff, at The Hague, has recently issued the first of the five volumes of a work entitled Enumeratio Systematica Fungorum. This work is a host index of the parasitic fungi of the European flora, and is chiefly due to the labor of the late Professor C. A. J. A. Oudemans.

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NATIVE VEGETATION AS A CRITERION OF SITE[1]

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The literature[2] of the past two years contains a number of discussions of methods of site determination, site classification and arguments for standardization. The arguments advanced in favor of the standardization of site classification are indeed very timely, since there is no method of site determination or classification in common use in North America at the present time. Some form of standard site classification is very desirable for scientific work, in the preparation of accurate forest descriptions and in forest regulation. However, as was evidenced by a discussion of this subject at a meeting of forest investigators held in Washington, D. C., during the winter of 1917, there seems to be a wide difference of opinion as to the basis for such a standard classification.

A satisfactory and convenient method of site quality determination is essential in the preparation of yield tables since the data on the yield capacity of the various sites are brought together in yield tables of comparable form. In fact, all volume, growth and yield data should be referred to site conditions.

[1] Delivered before the Society of American Foresters, at Pittsburgh, Pa., January 1, 1918. Contribution to a symposium on site classification; other subsequent papers being:

Bates, Carlos G. Concerning site. Jour. of Forestry, **16**: 383–388, 1918.

Frothingham, E. H. Height growth as a key to site. Jour. of Forestry, **16**: 754–760, 1918.

Roth, Filibert. Another word on site. Jour. of Forestry, **16**: 749–753, 1918.

[2] Roth, Filibert. Concerning site. Forestry Quarterly, **14**: 3–13, 1916.

Recknagel, A. B. What about sites? Proc. Soc. Amer. Foresters, **11**: 441–443, 1916.

Spring, Samuel N. Site and site classes. Jour. of Forestry, **15**: 102–103, 1917.

Watson, Russell. Site determination, classification, and application. Jour. of Forestry, **15**: 552–563, 1917.

Various criteria of site determination have been proposed at different times, among which may be mentioned:

1. Height of dominant trees at a given age.
2. Volume per acre of even-aged stands.
3. A formula site factor based on the basal area per acre, the average age of the stand and the height of the average tree.
4. Classification of the physical and chemical properties of the soil.
5. Fiber length of the wood.
6. Empirical personal judgment with no scientific or technical basis whatever.

The use of the height of the dominant trees at a given age appears to be the most commonly accepted criterion. However, some foresters maintain that height is an unsatisfactory criterion of site quality because the height frequently varies to a considerable extent with the density of the stand. Those who support this contention favor the increment of the arborescent species concerned, when judged by the measurement of an approximately fully stocked stand, as the best ultimate criterion of site quality.

It has been pointed out by Spring that the true quality of a given site cannot be indicated by the height or yield of a stand composed of a species which cannot fully utilize the physical factors of that site. A satisfactory expression of the relative productivity of different sites must fully recognize a proper correlation of the climatic and edaphic factors of the habitat with the silvicultural characteristics of the species. If an arborescent species is not well adapted to a given site it should not be used in comparing site productivity.

Zon[4] has shown that, for the purposes of future silvicultural management, the natural classification of forest stands should be based on the potentiality of the site instead of on the average height of the stand. The character of the tree growth is held to be the only reliable expression of the productive capacity of forest

[4] Zon, Raphael. Quality classes and forest types. Proceedings Society of American Foresters, 8: 100–104, 1913.

soils. However, the author further states that in virgin forests any difference in the physical factors affecting growth will become evident, not only in the character of the tree growth, but also in varying the composition of the stand or the native vegetation.

Cajander, while advancing rather radical arguments in favor of the living ground cover as a criterion and indicator of the physical conditions of the site in forests which have responded to the artificial cultural operations of silvicultural management, admits that the condition of the virgin forest itself should be used as the best criterion of the physical factors which affect growth.

Mell[6] has stated that there is a certain definite relation between the physical factors of the site and the growth and anatomical structure of the wood fibers and that site quality may be determined by a microscopical examination of the wood.

The writer[7] has previously advocated that foresters should avail themselves of the latent possibilities in the correlation of the native shrubby and herbaceous forest vegetation with the increment of the arborescent species, and in its use as an additional criterion in the determination of the relative productivity of forest sites. The use of native indicator plants is also advocated where increment data are meager or lacking. There are unusual possibilities for the forester in following up a line of investigation in a field equally as fertile as that opened by the physiological plant ecologist in correlating the native vegetation with the crop-producing potentialities of the land, the results of which have had a very practical application in modern agriculture.

While it is true that plant growth is dependent upon certain specific climatic and edaphic factors of the habitat, yet these combine to form a physiological complex which influences growth

Cajander, A. K. Über Waldtypen. Helsingfors, 1909. Fennia, **28**, No. 2, 175 pp.

[6] Mell, C. D. Determination of quality of locality by fibre length of wood. Forestry Quarterly, **8**: 419-422, 1910.

[7] Korstian, Clarence F. The indicator significance of native vegetation in the determination of forest sites. The Plant World, **20**: 267-287, 1917.

in a very definite manner. Therefore, in the determination of site quality a detailed consideration of the individual causal factors is not as essential as the combined effect, which is expressed in the resultant growth or increment. The native plants, in their response to the habitat factors, may be regarded as showing the effect of the summation of these factors as they influence growth.

The scientific study of forest vegetation must in the future accompany rational silvicultural and range management more closely than now, and in fact, as soon as possible, should precede it. The time has come for intensive investigations of this nature which will form the foundation upon which the superstructure of practical forest regulation will be built permanently. When the relation between the silvicultural characteristics and the physical factors which affect tree growth and the correlation of increment with the associated shrubby and herbaceous species are better understood, the different sites may be regarded as integral biological units which the administrator can use as a basis for the rational organization of his forest.

The importance of a correlation between the site factors and the silvical requirements of the arborescent species has been emphasized by Toumey.[8] The difficulty involved in the exact measurement of the physical factors of the site and the interpretation of the vegetation in terms of site factors is indicated. The herbaceous or shrubby vegetation can be used by the practicing forester in a field evaluation of the site factors, and in determining the site quality or the yield capacity. This method is particularly desirable when the productivity of a site must be assessed without the aid of forest trees.

In order to effect a proper correlation of site conditions, the forester must be well acquainted with the natural forest vegetation and the manner in which it is influenced by the physical factors of the site. The lack of a fundamental biological training is admitted by many foresters and is shown by the work of others. A training in the natural sciences is an absolute pre-

[8] Toumey, James W. Seeding and Planting in the Practice of Forestry. Pp. 40-43, New York, 1916.

requisite to research work in forestry, especially to a proper study of site and site qualities. Since site is regarded as an area considered as to its physical factors with reference to forest producing power, or the combined effect of the climatic and edaphic conditions of the forest habitat, it can be readily appreciated that in a consideration of the fundamental natural laws involved in a scientific study of the site the auxiliary sciences such as botany, physics, chemistry, meteorology, soils and geology, are concerned. In determining upon the indicator significance of the native vegetation a full appreciation of plant ecology, more especially the important principles of plant succession, must be realized. However, only a reasonable amount of systematic botany is considered essential to the practical use of the native shrubby and herbaceous vegetation as a criterion of site. The relative ease with which the proposed criterion may be applied by the field officer when the principles have once been worked out is a point in its favor. The average forest supervisor or ranger who possesses a sufficient knowledge of the local forest flora to administer efficiently the utilization of the forage resources of the administrative unit for which he is responsible should have no difficulty in recognizing the indicator plants after they have once been determined.

As suggested by Bates,[9] the increment of the arborescent species to be perpetuated under management, when determined by the measurement of an approximately fully stocked stand, is admittedly the best ultimate criterion of site quality. However, the native vegetation merits consideration as an entirely feasible criterion of site, to be used as an adjunct to the criterion or criteria which are based on the silviculturally important species. Where increment data are meager or are utterly lacking, the native vegetation on the area should serve as a valuable criterion of site quality.

In an integration of the vegetation it must be remembered that the behavior of the vegetation is a resultant function of the behavior of the component species. Therefore, the vegetation

[9] *Op. cit.*

of the association, society or community as an integral should be resolved to the individual species, to which indicator significance may be attached. In any ecological group of plants in which there are many diverse growth forms within a biological unit it is impossible to define accurately the boundaries of the association without encountering many overlapping species, especially in arid or semi-arid regions. An herb or a shrub can complete its full life cycle in a much shorter time than a forest tree; therefore, succession proceeds at a faster rate and a greater number of successional series may be observed than if the forest trees alone were under consideration.

The use of shrubby and herbaceous vegetation as forest site indicators may be applied with greater ease in the comparatively open, park-like forests of western yellow pine than in the denser Douglas fir, lodgepole pine, and Engelmann spruce forests. Changes in the density of the crown cover may change the composition of the vegetative undergrowth although the potential forest productivity of the site remains unchanged. Herbaceous plants are rather scarce in the denser forests except in partial openings or where the stand is below normal density. The character of the shrubby and herbaceous layers of forest vegetation is conditioned largely by the shade of the forest canopy. The forest floor in stands of fir, spruce and lodgepole pine is heavily and more continuously shaded than that of the densest stands of yellow pine. The proposed criterion is believed to be especially applicable to yellow pine forests or those of comparable density.

It is not the purpose of this paper to detail specific correlations between forest growth and the character of the associated vegetation. However, a few noteworthy cases in which the native vegetation presents rather conspicuous and convincing evidence of site character will be cited.

The studies conducted by the writer[10] in central New Mexico showed that, where two western yellow pine sites were recognized, the species limited to site I were mesophytic while those found

[10] . . . pp. 277–279.

on site II alone were decidedly xerophytic. The increment on site I amounted to 64% more than that on site II. The individual growth and development, luxuriance and density of the vegetation varied decidedly with site. The vegetation on site I was more luxuriant and vigorous than on site II where it was comparatively sparse. A rather cursory comparison of the forest vegetation of various sites within the range of the Rocky Mountain variety of western yellow pine (*Pinus ponderosa scopulorum*) occurring in New Mexico, Arizona, Utah, and Colorado shows certain striking parallelisms and at the same time differences which can only be attributed to site. Again chaparral areas composed of *Quercus gambelii*, *Amelanchier alnifolia*, *Arctostaphylos pungens*, *Ceanothus fendleri*, and other shrubby species are reputed by some to be potential western yellow pine sites. An examination of such areas in the Intermountain Region reveals few western yellow pine associates among either the shrubby or herbaceous vegetation, which results in the attaching of considerable doubt to the statement that such areas are potentially western yellow pine sites.

In central and southern Utah between elevations of 6500 and 7800 feet above sea level *Quercus gambelii* is the dominant species on all exposures except the south, with *Amelanchier alnifolia*, *Prunus melanocarpa*, *Rosa fendleri*, *Acer grandidentatum*, *Symphoricarpos oreophilus*, *Berberis repens*, *Purshia tridentata*, *Pachystima myrsinites*, and *Artemisia tridentata* occurring in varying mixtures. In the brush scattering individuals of *Juniperus scopulorum*, *Abies concolor*, *Picea parryana*, *Pseudotsuga taxifolia* and very rarely a specimen of *Pinus ponderosa scopulorum* may be found. When the nature of the soil as well as the growth and reproductive power of *Abies concolor* and *Pseudotsuga taxifolia* on these areas are considered they are regarded as belonging to the potential fir type. On ridge-tops and south slopes *Arctostaphylos pungens*, *Peraphyllum ramosissimum*, and *Ceanothus fendleri* become the dominants while *Quercus gambelii*, *Symphoricarpos oreophilus*, *Amelanchier alnifolia*, *Berberis repens*, *Cercocarpus parvifolius*, *Purshia tridentata*, *Pachystima myrsinites*, *Artemisia tridentata* and *Eurotia lanata*

are secondary species. *Juniperus utahensis* and *Pinus edulis* are found scattered through the brush, which clearly indicate the potentiality of these ridge-tops and south slopes. In northern Utah and southern Idaho *Quercus gambelii* is largely replaced by *Ceanothus velutinus* which is here indicative of potential *Pseudotsuga taxifolia* sites.

In central Idaho *Purshia tridentata* is found on the poorer *Pinus ponderosa* sites. A tall, dense, luxuriant growth of *Physocarpus malvaceus*, *Ceanothus sanguineus*, as well as the presence of *Vaccinium membranaceum*, *Rubus parviflorus* and *Ribes viscosissimum* are considered indicative of *Pseudotsuga taxifolia* sites.

Thorough scientific investigations should not only solve the above problems but also should contribute much toward the intelligent selection of forest planting sites. Obviously, these studies should also include a study of plant succession extending over a rather long period of years. The natural variations or succession of the native vegetation must not be forgotten. Wide variations due to extraneous factors, such as fire, must also receive proper interpretation. Changes in the soil caused by fire may also cause temporary differences in the character and distribution of native vegetation. It is contended by some that plant indicator studies should be resolved eventually to terms of the soil since the effect of site conditions is indicated by the character of the subterranean parts of the native plants. This is inadvisable because, as indicated above, we are really concerned with the combined effect of the site on plant growth rather than with the component factors. However, until the correlation has been definitely determined, the soil and other important factors should receive sufficient attention to enable a comprehensive correlation of increment with the native forest vegetation and to make proper deductions as to the relative importance of the limiting factors. Plant indicator studies should also yield valuable data on the ecological relations of forest trees and their associates.

In conclusion, it is urged that, in the determination of site, no one criterion should be adopted to the positive exclusion of

other feasible criteria since it may be found that one may serve as an excellent check on the other or may even more closely indicate the true potentiality of a given site quality. While a standardization of technique or methods is highly desirable, latitude should be given for a careful correlation of all feasible criteria and a proper interpretation of their significance. In previous discussions of site determination in North America, little or no attention has been given to the consideration of the indicator significance of native shrubby and herbaceous vegetation in the classification of the potential productivity of forest lands. This criterion should be of the utmost value not only in determining the relative productivity of forest sites, but also in explaining the presence or absence of tree growth on certain areas and in the judicious selection of the proper species and suitable sites in reforestation work.

AN IMPROVED COLORIMETER FOR COLOR INHERITANCE STUDY

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The necessity for an improved standard type of colorimeter available for the quantitative study of color values has long been felt by workers in plant physiology and in genetics. Several types of color apparatus are now upon the market. The writer's experience has been with the type known as the tintometer, an apparatus which has long been quite generally employed for commercial purposes, and which is in use at several of the experiment stations in the United States. Finding the original instrument unsatisfactory from certain standpoints, the writer undertook a series of experiments in its reconstruction and mounting which may be of value and interest to geneticists and others engaged upon problems involving colorimetric determinations.

In substance the original instrument is a binocular of wood, supported in an inclined position. The object, the color of which is to be determined, is placed in a hollow tray under the right hand tube of the binocular. Under the left hand tube is placed a similar tray containing chemically pure calcium sulfate, intended as a standard white reflecting surface. In the end of the left hand tube of the binocular is fitted a small rack into which certain colored glass strips are placed. These are made up in graded intensities of the three primary colors, and are alternately placed in the rack until such an adjustment of the three colors is reached as gives a combined color effect to the left eye, similar to that produced on the right eye by the colored rays proceeding from the object itself. These colored glasses bear no direct relation to the spectrum colors, but are founded as a base on the colors produced by fractional normal solutions of three different chemical compounds. The glass of each of the

colors, red, yellow and blue, lowest in intensity, is the one directly matched to the chemical solution taken as a base. The entire series of unit glasses consists of 163 in the red, 146 in the yellow and 155 in the blue. In each of the colors, the series begins at the lightest tint with 0.01, and reaches the deepest shade at 20. The intervals of tint are at first 0.01, then 0.02, finally from 1 up to 20, the intervals are 0.05.

While it is true that absolute purity of color is nowhere obtainable except through the isolation of a solar ray of a wavelength which is interpreted by the eye in terms of that color, yet for practical purposes there are many difficulties in the way of the utilization of the color spectrum as a standard.

The original tintometer is a very simple instrument consisting of a wooden binocular frame without a lens, through which the left eye sees the object the color of which is to be determined, while in a holder at the end of the right hand tube of the binocular are placed colored glass strips, graded in graduated intensities of the three primary colors as stated. From a series of these, those are gradually selected by successive trials, which transmit such a mixture of rays as matches the color of the object seen through the left hand tube. Underneath the color glasses is placed a tray containing chemically pure calcium sulfate, forming a standard white reflecting surface.

The writer has found the apparatus practically useful for color determinations in the study of color inheritance. In order to render the use of it more practical and convenient, it was found desirable to introduce a number of improvements which have been added to the original apparatus. As the instrument now stands, the writer believes that it will prove practically useful to plant physiologists and geneticists engaged in research work involving color determinations, for the quantitative determination of color. No patents have been applied for on the mechanism and any laboratory is free to make such use of the illustrations and drawings as it may desire.

The writer's improvements on the original apparatus consist essentially of a mechanism carrying two revolving steel spindles, each holding a glass cylinder capped at its outer end. In these

cylinders are placed, in the left hand one, the substance the color of which is to be determined, in the other, the calcium sulfate used as the standard white reflecting surface. The spindles

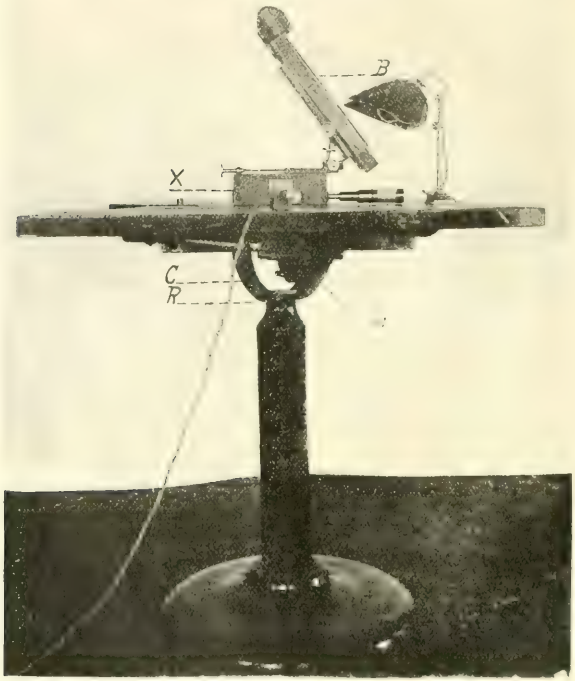

Fig. 1. Tintometer as reconstructed and mounted. *B*, binocular; *X*, case containing drive mechanism; *M*, motor; *C*, three-arm support; *R*, point of rotation.

are rotated at high rate of speed by a friction drive mechanism which is reversible. By this rotation of the substance the color

of which is to be determined, inequalities in its surface, if any exist, are obliterated, and it becomes optically observable as a uniform color mass. A set of focusing screws is supplied for adjusting the position of the binocular vertically and laterally in relation to the two revolving glass cylinders.

In the accompanying illustration, figure 1 gives a general view of the complete apparatus as mounted. The instrument, *B*, driving gear and motor are mounted upon a table of hard maple supported upon a stand consisting of a three-arm iron

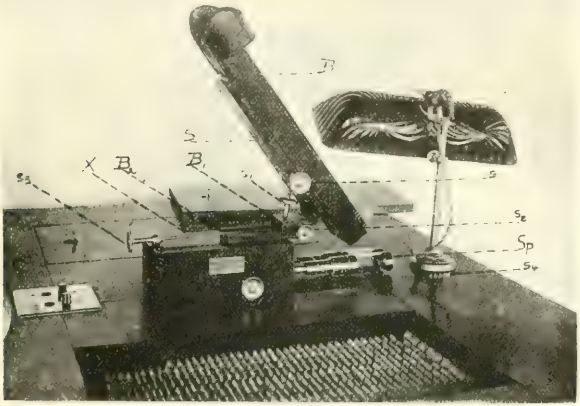

Fig. 2. Tintometer as reconstructed: top view of table showing method of mounting, rotary cylinders and unit color glasses. *B*, binocular; slide support for it; B_1, hinge-base; B_2, bed-plate; *X*, case containing drive mechanism; *Sp.*, rotary spindles with cylinders; s, s_1, s_2, s_3, screws for regulating position of binocular; s_4, screw for changing direction of rotation.

casting, *C*, resting upon an iron pillar and base, upon which it revolves at *R*. The motor actuating the drive mechanism for rotating the spindles, is suspended beneath the table between the supporting arms, at *M*.

In figure 2 is shown a closer view of the upper surface of the table, in which the glass color units are seen sunken in an open

tray, which is carried by a removable lid when the apparatus is not in use. Close approach to the binocular eye-piece is secured by a curved-in cutting of the table, partly shown in the illustration, in front of which is a double flush-plate switch, controlling both the motor and the lights. The binocular is further provided with a hood, lacking in the original instrument. In figure 1, *B*, the tintometer binocular, is attached to a wooden support *S*, upon which it slides by a rack and pinion arrangement worked by the focusing screw, *s*. This enables the apparatus to be brought within proper observing distance from the revolving spindles. The support *S* is hinged to a base *B*, and rests back upon the

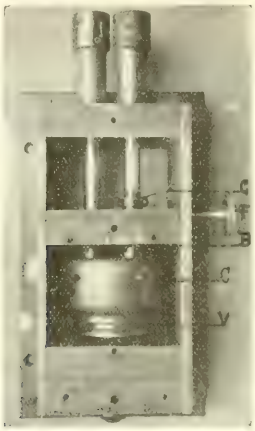

Fig. 3. Top view of case, showing annular, *C*; pulley groove, *V*; fiber gears, *B*; reversing screw, F; reversing lever, G.

top of a screw S_1, by which the slope of the binocular can be adjusted. The base *B* in turn slides as a whole upon a bed plate B_1, which is moved backward and forward by means of a screw S_2, and the upper part of it is moved laterally across the spindles, *Sp* by means of the screw S_3. It is thus possible to get four different sets of adjustments for the apparatus as reconstructed. At S_4 is a screw which reverses the drive mechanism.

In figure 3, the lid of the metal case, illustrated in figures 2 and 3, is removed, and an upper view is furnished of the drive mechanism. The annular is shown at C within which are seen at A the ends of the spindle axes, which terminate within in fibre friction gears.

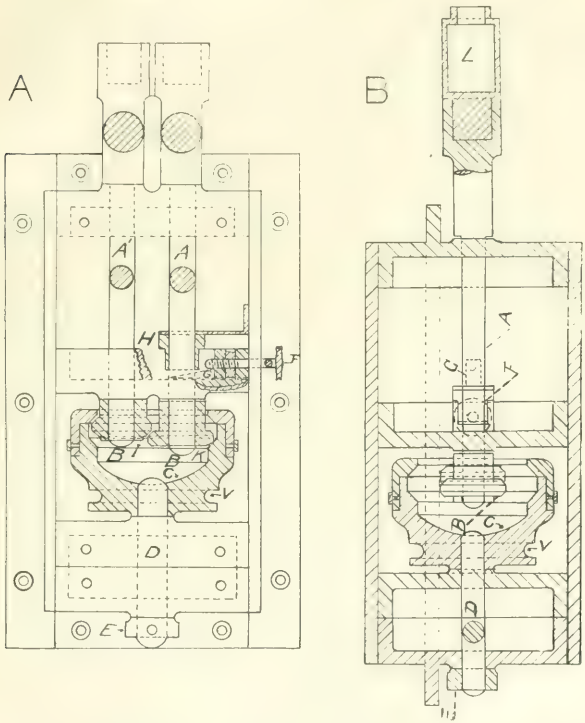

Fig. 4A. Horizontal section of drive mechanism showing: A, A_1, spindles; B, B, fiber gears; C, annular; V, groove in annular for pulley cord; D, spindle for annular; E, collar for annular; F, screw for reversing spindles; G, lever.

B. Vertical section of drive mechanism. A, spindle for cylinder; B, fiber gear; D, spindle for annular; C, annular; V, groove in annular for pulley cord; E, collar for annular spindle; F, reversing screw; G, lever.

Figure 4 A is a transverse sectional drawing of the drive mechanism, reduced about one-third. Spindles A and A_1 are rotated by friction discs B and B', making contact at K and I on annular C, which, in turn is operated by a motor drive (M, in fig. 1), connected with the annular gear C, by a round belt at V. By turning a thumb-screw F (S_4, in fig. 2), spindle A may be shifted so that contact can be effected at I between the friction discs B and B', attached to spindles A and A', thereby releasing contact at K, and effecting a reversal in direction of rotation on the part of spindle A. The shifting of spindle A is accomplished by the thumb-screw F forcing the wedge G against the collar H, which is held in place on spindle A by means of a set-screw. The annular C, is carried on spindle D, which is held in place by collar E. Figure 4B shows a lateral longitudinal section of the drive mechanism, the parts being lettered to correspond with figure 4.

A further improvement upon the mode of use of the original tintometer, lies in the employment of artificial light of constant quality and value instead of ordinary daylight. It is plain that in the employment of daylight as a means of illumination several sources of error are presented. The relative intensity of the different spectrum rays varies according as the sun is overhead or near the horizon. The available rays in solar illumination vary also according to the absorption spectrum of the surrounding surfaces. It is manifest that a color determination with the tintometer will not be the same for the same object when a red brick wall opposite the laboratory is replaced by a green field or a mass of white buildings. A laboratory window admitting only a north light from a clear sky would be reasonably satisfactory, except for the difference in the absorption spectrum due to the apparent position of the sun with respect to the earth's horizon from morning to evening and during the solar year. Added to these variations, which have to do with local disturbances in the relative spectral content of the available solar rays, there is the added practical difficulty of using the tintometer at all during dark gloomy weather.

It has therefore been arranged to use the instrument in a ventilated dark room, using two 25-watt tungsten lamps as the source

of illumination, the light from which is directed down upon the glass cylinders by a shade reflector. The degree of constancy of the current supplying the lamps is ascertainable by means of a voltmeter.

The principal difficulty in the construction of the improved instrument has been to obtain proper glass for the cylinders. A perfectly white glass tubing of definite and known composition, of proper diameter, with a comparatively thin wall, and free from defects, has been difficult to find. In order that the reflecting surface and the refraction index of the wall of the cylinder should be identical throughout its length, and to get rid of the linear striations present in the best glass tubing, an attempt was made to have the interior and exterior faces of the cylinders cut to a uniform thickness throughout and polished. The practical difficulties in the way of accomplishing the cutting, proved, after much experimentation, to be insuperable, except at a cost that would be prohibitive. The writer therefore was obliged to content himself with obtaining the most satisfactory white standard glass tubing possible. By always using the same make of tubing after it is once settled upon, variations in the readings due to differences in the absorption spectrum of the glass of the cylinder will be eliminated.

The rotary cylinder mechanism enables a far greater variety of opaque substances to be successfully determined for color than was possible with the original instrument, and the fitting-out of the binocular with a set of three-way adjustments, enables the instrument to be satisfactorily oriented with respect to the revolving cylinders. Of course, in the case of liquid substances for which the color is to be determined, or of amorphous powders, the rotary mechanism would not be necessary.

For the quantitative measurement of color value in flowers, in the study of color inheritance, the writer has found the apparatus invaluable, and it seems likely that it will prove useful generally to investigators. In working on color-inheritance in *Pelargonium*, it is found that clear and definite results in stating the color values of segregates are obtainable with this apparatus. By supplementing these records with Lumière color photographs a practically perfect series of inheritance records is obtainable.

BOOKS AND CURRENT LITERATURE

MONOGRAPH OF THE CACTACEAE. For seven years Britton and Rose have been engaged in the preparation of a monograph of the Cactaceae, which is destined to supersede Schumann's Gesamtbeschreibung der Kakteen as the authoritative treatment of this family. Through the aid of the Carnegie Institution it has been possible to explore the cactus regions of South America, as well as to examine types in European herbaria and to maintain living collections for study. The inadequacy of herbarium material in representing the characters of cacti and the large number of names based on incomplete descriptions of living plants has made the task of the authors a very difficult one. It is planned to issue the monograph in four volumes, the first of which has just appeared,[1] covering *Pereskia*, *Opuntia* and related genera. The genus *Opuntia* is the largest of the family, containing 254 species, and has been divided into three sub-genera, Cylindropuntia, Tephrocactus and Platyopuntia, containing respectively 13, 4 and 29 series. Of these series 31 have representatives in North America and 15 are confined to South America. Keys, descriptions, bibliographical references, and citations to illustrations are given, and nearly every species is illustrated by colored plate, half tone or line cut. The volume has been published in most sumptuous form, but it leaves the reader with regret that the ancient practise of illuminating monographs with colored plates, whose cost is out of all proportion to their value, has persisted to this late and practical day.

From the systematic standpoint the work is notable for the fresh grouping of the species in this large genus, for the elucidation of the poorly known South American species, and for the conservatism with which the North American forms have been treated. Under *Opuntia opuntia*, for example, 21 specific and varietal names have been reduced to synonomy, under *O. engelmannii* 11 names, and under *O. lindheimeri* 20 names. In many cases the relegation of names to synonomy has been due to inadequacy of the type material, uncertainty as to the exact

[1] Britton, N. L. and Rose, J. N. The Cactaceae; descriptions and illustrations of plants of the cactus family. Vol. I. Carnegie Inst. Wash. Publ. 248. Pp. 236, pls. 36, text figs. 302. 1919.

type locality, or even to the description of new forms from living plants. In many other cases it is due to the difference of opinion which exists between the authors and other cactus students regarding the limits between the perplexing array of closely related forms that may be found in the field in any region where these plants are abundant. The opuntias are preëminently a group in which prolonged and careful field work is necessary to determine the influence of the age of the plant, the relative age of different joints, recent climatic conditions, character of soil, and many other conditions, on the general habit of the plant, the form and size of the joints, the character of the armature and even the color of the flowers. Among those to whom a taxonomic grouping is the instrument of work, rather than the material, there will be much satisfaction in the appearance of a monograph in which the "lumping" of species has been generously done. We have been made to believe in recent years, however, that it is the business of systematic botany to describe and classify all plant forms which possess even a single well-marked and constant character differentiating them from their nearest of kin. Anyone to whom the cacti of the United States are familiar under their native conditions will be likely to ask whether this departure from recent taxonomic practise has been begun in the right place and whether it has been impartially applied to the southeastern and West Indian forms as well as to the southwestern ones. When such indistinguishable forms as *Opuntia littoralis* and *O. occidentalis*, of the California coast, have been retained in separate series of the genus, and when *O. pollardii*, of the Mississippi coast, has been retained as separate from *O. opuntia*, partly on such a character as the turgidity of the joints, one may well ask why such a form as *O. blakeana* has been reduced to synonomy with *O. phaeacantha*, in spite of its well marked characters and distributional separation, why the very local and clearly distinct *O. dillei* has been relegated to the "lump" known as *O. engelmanni*, or why *O. fulgida* and *O. mamillata* have been combined in spite of their differences in habitat and vertical distribution and the fact that they can be readily distinguished in the field at a distance of 200 feet.

In spite of these and many other inevitable differences of opinion that are sure to exist among students of cacti, there will nevertheless be a very general appreciation of the masterly work which Britton and Rose have done in an extremely difficult group.—Forrest Shreve.

THE UTILITY OF SOIL SURVEYS.—In a recent publication of the University of California R. L. Pendleton[1] describes the results of an extensive laboratory and greenhouse study designed to test the degree of correspondence between the mapping of soils by the United States Soil Survey and the properties of the same soils under controlled conditions. Twenty-four samples were collected, representing four soil types as mapped. The mechanical analysis was obtained both by the Hilgard elutriator and by the method of the Bureau of Soils now accepted as standard. Chemical determinations were made of nitrogen, humus, calcium, magnesium, phosphorus and potassium. Bacteriological work included tests of ammonification, nitrogen fixation, and nitrification. Greenhouse tests were made with a number of common crop plants, but not with all crops on all soils. Although Pendleton refrains from criticism of the methods or results of the Bureau of Soils, his data are somewhat damaging to the assumption that soils mapped by the Bureau as of the same type are really closely similar. All chemical, bacteriological and crop-culture tests showed wide variations. The mechanical analysis, upon which the classification methods of the Bureau of Soils so largely rely, showed that six of the twenty-four collected samples did not belong physically to the soil types which they were supposed to represent. The samples were collected by Pendleton personally. He had had experience in soil mapping under officers of the Bureau of Soils, and was experienced in the methods used. The reviewer has worked with Mr. Pendleton in the field and can testify that his methods and habits of work are exceptionally thorough and careful. The reviewer does not believe that the failure of Pendleton's samples to be what he thought they were can be ascribed to carelessness or unusual personal error.

The work described was carried out in 1915 and 1916 under the direction of Chas. B. Lipman of the University of California. Lipman contributes to the monograph a preface some sentences of which deserve wide publicity and consideration. After explaining that the paper has been seen through the press by him in the absence of Pendleton from the country, Lipman goes on to say: "My own general conclusion from the results obtained by Mr. Pendleton is that they cast grave doubt on the validity of the Bureau of Soils method of soil classification and map-

[1] Pendleton, Robert Lairmore. "Are soils mapped under a given type name by the Bureau of Soils method closely similar to one another?" Univ. of Calif. Pubs. in Agr. Sci. 3: 369-498. 1919.

ping, and, incidentally, on all methods devised for that purpose to date. I cannot see how such methods can serve us in scientific work at all, and, from the practical standpoint, it would surely seem that guides for the purchasers of land could be arranged more cheaply and less elaborately than by the soil mapping methods extant. This statement has particular reference to the subdivision of types very minutely, such as, for example, sandy silty clay, clay loam adobe, etc. Such minute classification and subdivision in view of the present state of our knowledge of soils, is analogous, in my opinion, to carrying figures out to four decimal places when it is known that the accuracy of the method makes it impossible for them to be correct beyond the first decimal place. In support of this seemingly radical conclusion, the reader will find much of interest in the recent studies of this laboratory on variability in soils, which have already appeared in this same series."[2]

With the ideas expressed by Lipman the reviewer is in full accord. Some experience in the attempted use of the Soil Survey maps both in scientific investigation and in practical land valuation has resulted in the conviction that the soil maps are so dependent upon academically rigid criteria of classification as to be of little practical use and are insufficiently precise and thorough for scientific purposes. From the greater emphasis placed in recent years on the making of the more general "reconnaissance surveys," one suspects that the officials of the Bureau of Soils have realized this situation. These reconnaissance surveys seem to the reviewer much more useful practically than the detailed surveys and they are presumably far less expensive per acre. The entire abandonment of the detailed survey as now conducted might not be an important loss, especially if the funds and energy thus released could be devoted to a renewal of fundamental investigations of soil science like those for which Whitney and the Bureau of Soils were once so viciously attacked and are now so generally honored. The reviewer suspects, with Professor Lipman, that refinement of methods of soil surveying and absorption in the attempt to perfect detail have obscured a little the real, or at least the original, objects of the effort. There is an ancient Chinese tale of one Fu Wang who desired to see the Emperor. Knowing that on a certain day the Son of Heaven would pass through a walled street adjoining his garden the industrious Fu

[2] Of the studies referred to by Prof. Lipman, two are known to the reviewer: Waynick, D., Univ. Calif. Pubs. in Agr. Sci. **3**: 243–270 (1918); Waynick, D., and Sharp, L. T., *Ibid.* **4**: 121–129 (1919).

began the construction of a tower from the top of which, in safe seclusion, he might view the entourage. However, the foundations of the tower involved architectural problems of the greatest interest. Doubtless a tower of sorts could have been built without foundations, but this would not have been becoming to a careful and scientific man. Sadly enough it happened that Fu was still working, quite successfully, at the foundations when the Emperor went by.—E. E. FREE.

NOTES AND COMMENT

The publication of Botanical Abstracts has already advanced to a point that makes it one of the indispensable tools of the working botanist. There has perhaps never before been a project in the history of our science which has at the very outset elicited such a large amount of gratuitious coöperation. Nearly 3000 titles will have been abstracted in the first two volumes, and it is estimated that between 5000 and 6000 entries will appear in the volumes for 1920. The excellent and thoroughgoing plan by which practically all of the world's periodicals containing botanical matter have been assigned to collaborating abstractors gives assurance that the future volumes of Botanical Abstracts will very thoroughly cover the field of pure and applied botany. The journal now has about 1000 subscribers, and it is worthy of note that over one third of this number are outside the United States and Canada. The unhampered growth of this valuable publication will depend on securing a still larger subscription list, and it is to be hoped that the same spirit of coöperation that has filled its pages will actuate every American botanist to do all he can to increase its circulation.

There is probably no case in which American horticulture has been more dependent on foreign importations than in the matter of securing bulbs of the tulip, hyacinth and narcissus. The popularity of these plants is attested by the fact that nearly two million dollar's worth were sold annually in the period prior to the war, of which number only twenty-five thousand dollar's worth were produced in America. Dr. David Griffiths and Mr. H. E. Juenemann have recently written a bulletin (Department of Agriculture Bull. 797) describing the methods of growing and handling these plants and indicating the extent to which their production may be increased in the United States. The bulk of our crop is grown on the north Atlantic seaboard and in the extreme northwest. The authors show that the cultivation may be extended to the Ohio and upper Mississippi valleys and that the selection of proper varieties will make it possible for us to produce our own "Dutch bulbs" over an even greater area.

The presence of rubber in the common rabbit-brush (*Chrysothamnus nauseosus*) of the Great Basin region and interior California led to an extensive investigation of the plant during the war. A recent publication by H. M. Hall and T. H. Goodspeed gives the results of the field and laboratory work, and indicates that this wide-spread plant possesses in the aggregate an amount of rubber that might be of great value under conditions curtailing our foreign supply. An average of 180 analyses gave 2.83 per cent of rubber in one variety and slightly lower percentages in others. Chrysil, as the new rubber has been designated, occurs mainly in the cortex and medullary rays of the larger stems and upper portions of the root. The varieties growing in alkaline soil are the richest in rubber, which promises a possible future for these useless lands.

Mr. Albert F. Hill has contributed a paper on the Vascular Flora of the eastern Penobscot Bay Region, Maine, to the third volume of the Proceedings of the Portland Society of Natural History. This particularly rugged portion of the Maine coast has a flora of 747 species and varieties of native and introduced plants. The author discusses the geographical affinities of the flora and the floristic history of the region, particularly as influenced by the glacial period.

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SOME FACTORS IN RESEARCH[1]

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When I accepted the invitation of the Council of the Botanical Society to present a paper on some phases of research I did not realize that in this reconstruction period there would be so many hammers in use pounding one part or another of the structure of botany and placing a new superstructure upon it in America. However, since the hammer is being used constructively, on the whole, perhaps it is just as well that I also have selected this as one of the tools with which to work today. I take it that the whole spirit of this program is to signify that American botany intends to throw off any indolent satisfaction or pacifism and become warmly assertive, with the avowed purpose of making the science as a whole a greater national force and asset.

Broadly speaking, the factors in research are all those conditions which facilitate not merely immediate productive effort, but which likewise lay the foundation for consistent and sustained progress in the time to come. For the last mentioned reason some of the things which I have to say have to do only vaguely with the immediate factors in research; and where the latter may be specifically identified, I shall limit myself more particularly to considerations arising when one takes merely a physiological view point.

The science of physiology—or plant physiology, as we are forced to call it—is virtually a new one in this country; rather, it is only within about the last twenty years that it has been free to thrive in more than a few restricted environments. I have here in mind the concept of plant physiology as the whole science of the living plant in action,—the physics and chemistry of life processes, the correlations of organs, tissues, or cells, and the

[1] A symposium paper read before a joint meeting of the Botanical Society of America and the American Phytopathological Society, Baltimore, December 27, 1918, as a phase of the general topic "Our Present Duty as Botanists."

relations of the plant as a whole, or of its parts, to internal and external factors. The static and the dynamic study of vegetation may perhaps be separated off as ecology, but there is no logical subdivision of physiology on the basis of simplicity or complexity of organization. The physiology of the bacteria, of the fungi, of the algae, and of all higher classes of organisms is fundamentally the same.

For practical purposes it is possible to associate certain phases of abnormal physiology with certain phases of anatomy, histology, and more particularly mycology, under the caption phytopathology. Even so, however, much that is fundamentally pathological may not be logically extricated from that which is non-pathological, and physiology may legitimately concern itself with a certain, at present ill-defined, phase of phytopathology, including the so-called physiological diseases. Indeed, however narrowly or broadly we may define either field, pathologists must, and the majority do, recognize that one or more of the legs of their chairs rests on the foundation of physiology. Although expressing the close relation between pathologists and other botanists Dr. Lyman has persisted in using the expression "pathologists and botanists"—just as one might say hash and chili con carne; yet both are made from yesterday's beef, and the difference lies chiefly in the seasoning. I cannot let pass unchallenged the statement that the pathologist must be essentially a mycologist. I have greater hope for the pathologist, for I believe that research in his field is inseparable from research in physiology; that is, pathology deals not merely with the causal organism and the affected host but with all growth relations and interrelations of both. To demonstrate this is a part of our duty as physiologists.

In much the same way as for pathology one may segregate as a distinct subject certain aspects of "bacteriology." One may relate the last-named science in part to taxonomy and morphology, to medical science, and to a variety of industrial "departments." Nevertheless, these relations take nothing whatever from the fundamental physiological aspects of bacteriology as a whole; for in this entire field morphology is secondary, while

metabolism (in the broadest sense) and life relations offer endless possibilities in research.

I will not enter at this time into a comprehensive discussion of the research relations of physiology to other fundamental and applied sciences, but will only use a few instances of such contact in the hope of establishing a broad basis for the subject—with the feeling that such breadth is always a dominant factor in a wholesome, well-rounded concept of research. The various phases of research in any general field are ultimately so interrelated that any great and consistent progress in a narrow section of the field is—on the whole—dependent upon general progress in the entire field.

It is practically possible to dissociate biological chemistry and physiological chemistry from physiology, because animal physiology has in the past restricted itself more or less definitely on account of the complex correlations in the animal body. Referring to plants alone, however, there would be little or no reason for the use of the term physiology if we dissociate it from the biochemical aspects. Without their biochemical bearing what would be left of metabolism and enzyme action, of photosynthesis, permeability, and toxic action, to mention only a few divisions of this subject? Imagine at this time, if one can, the stimulus to research in a plant physiology including only the physical and —let us call it—"correlation" problems. Later when we shall have bio-physics (and there have always existed individual biophysicists)—then plant physiology would be a "miscellaneous" drawer in which to deposit for safe keeping the little known and unclassifiable, the unclaimed and borderland problems, the kicks and the contentions.

Here and there horticulture has accomplished something in research, but on the whole the organizations of modern horticultural departments have been failures in accomplishing real horticultural research. This, however, is as might be expected. Practical gardens and orchards were sown, and garden and orchard practice have been reaped. Horticulture touches many sciences (it also effectively touches legislatures) and thereby offers innumerable research opportunities and great possibilities in equip-

ment; but it offers these as research factors to physiologists, pathologists, and geneticists—all botanists—not to men with merely practice and managerial training. The chief factor, therefore, for our consideration as physiologists, in broadening the horizon for research, is that of fostering contact with horticulture in order to know sympathetically the problems which grow out of it, and to be in position to assume such problems. It is absurd to condemn it and stand aloof.

The same thing can scarcely be said of agronomy—using this term in its broadest sense—because agronomy has in some measure kept in fairly close contact with chemistry, with soil physics, with physiology, and with bacteriology. Indeed, soil science is in part all these things. Even here, however, it would be far more advantageous to a unified botany to use our influence to the end that, where fundamental physiological research is planned, appointments be urged and be made specifying physiological research.

In this connection, moreover, much might be said in regard to the establishment of research positions in various industrial enterprises, such as drug manufactures, seed houses, and other plant-exploiting industries. A move in this direction has been made recently where a progressive drug manufacturing concern in the Middle West, which formerly employed only chemists and animal pathologists, has seen the wisdom of appointing a research plant physiologist, offering an opportunity to undertake investigations in any direction, whether immediately useful or not, which may be related to its enterprise. Agriculture is not our only point of contact with industry. To any one who has looked over the field it must appear deplorable that there exist in this country few, if any, experimental zymological or fermentation laboratories connected with industrial enterprises, yet we all know what has been accomplished in Copenhagen, in Vienna, and elsewhere. In fact, much of the physiological aspect of microbiology as related to industry other than agriculture is in a dormant stage. Wherever opportunity permits we should inject the necessary hormone—I say hormone because that seems to connote more than purely chemical relations.

One of the strongest factors in fundamental research is the capacity to develop new methods and new apparatus as the newer problems are approached. I anticipate stimulation rather than inhibition as a result of the greater independence of our work, especially in relation to German work, due to the war. The importance of American inventive genius has always been felt in mechanical inventions particularly, but we see this same quality now dominant in the methods employed and the apparatus designed for investigation in the basic sciences during the past ten years or so. Without the micro-nitrogen methods and the amino-nitrogen devices, without the American work on lecithin analysis, and especially that on vegetable proteins and nucleic acids, biochemical science would not have reached its present goal. The recent work on the measurement of osmotic pressure is a standard of excellence, and even oxidase measurements have become quantitative. In the field of hydrogen-ion concentration pioneer work was done and later both colorimetric and electrometric methods advantageously standardized.

In the field of physiological ecology some striking advances are in the determination of the wilting coefficient of plants, methods for the investigation of the evaporating power of the air and the relation between transpiration and evaporation, the experimental method as applied to field ecological study and the effects of bog waters upon vegetation.

In recent times fundamental researches have been contributed on the "hydration" relations of the colloids and the effects of salts and other compounds upon the hydration capacity, contributing somewhat, perhaps, to the intricate factors in growth. Nowhere has the physiology of the bacteria and of the fungi received such careful study with special reference to nutrition and to the differentiation of species through their physiological activities, and new methods of approach have been the key to this success.

The study of antagonistic salt action has been followed most completely, and practically speaking the recent developments in this field have been largely American. In fact, as one looks through the various major topics in the field of physiology it is

found that energetics, photosynthesis and chlorophyll action alone are those which have in this country invited relatively little consideration, although investigations now in progress—the preliminaries of which we have heard—afford indication that the photosynthetic mechanism will not long remain fundamentally unexplored.

We have scarcely yet admitted a confidence in American botanical research, but confidence is desirable, and an appreciation of whatever may be fundamental is better. Perhaps, more even than we are willing to acknowledge, we have accepted past German superiority and applied it to the present. Let me point out one instance. Although we all revere the memory of Dr. Eduard Strasburger, and know full well the debt of American cytology to his influence upon American students, yet it seems to me that we do not realize or adequately emphasize the smallest fraction of the debt which he owed to his American students. Strasburger himself recognized it and declared it. When we then recall the work done in Europe by Campbell, Humphrey, Mottier, Harper, Fairchild, Swingle, Chamberlain, Davis, Allen, Overton and a host of others who gave to their teacher inspiration and knowledge of technique, while displaying powers of careful observation and deduction, we begin to see that American botanists have not been takers merely, but givers in full measure. Moreover, if you have worked in that atmosphere and have personally felt the spirit and seen the material advances left in the wake of the American student, there can be no question that this German laboratory profited well from its American association. It matters not that the old cytology seems to be rounding out its existence; the record of accomplishment is full, and the promise for future confidence in a world competition may be abundantly sustained. American physiological literature will doubtless never again fail to receive the recognition which is justified. We have no desire to be critical of the science in other countries, and much may be said in extenuation of the circumstance that our experiment station publications are most frequently disregarded. The very diversity of the material offered has made adequate consideration difficult; but outside of such cases it is

safe to assert that no small amount of the work published on this side of the water has been systematically overlooked. English and French (no less than German) investigators in the field of plant physiology are not free from this criticism. Nothing will correct this more promptly than the development of a high standard of American journals and particularly the development of our new abstract journal to the highest perfection of its kind. The criticism which is mentioned above is not, however, applicable to foreign botanists alone, but in many instances it applies also to some among us. Due to our educational associations, especially in Germany, we may have laid altogether too much stress upon relatively insignificant German publications, and we have seen through rose-colored glasses the accomplishments of many of their investigators, particularly in phytopathology.

Immensely serviceable in furthering research would be the greater availability of special equipment. Library material is used by those living far and near, and I believe that the extension of opportunities and inducements to use special equipment, particularly during the usual vacation period would meet general approval. Let us take one or two examples. Surely it is not yet necessary for every laboratory in the country to develop an expensive equipment for the control of humidity and temperature in greenhouse compartments. Yet an effective equipment of this type would offer a means of solving a variety of problems confronting the physiologist and pathologist.

Similarly, as physiologists and pathologists, we are practically all finding ourselves compelled to employ methods of hydrogen-ion determination as a part of every-day technique. The indicator method is extremely serviceable—as a result of excellent work done in this country—and while simple and accurate enough for ordinary purposes, there are times when we must know that our standard solutions are accurate. This is particularly true, of course, where the chemical equipment is meager. It is not possible for every laboratory to install and maintain equipment for the gas chain method, therefore it is conceivable that the establishment at various centers of standardized electrical methods, employing potentiometers, might solve the present difficulty.

There are doubtless many physiologists today who hesitate to consider hydrogen-ion concentration as a factor in their work because of imagined difficulties in the process. Yet this is one of the factors which enters into every fundamental study of the soil relations or the solution relations of plants, of the activity of microorganisms in fermentation phenomena, and of the proper study of most *in vitro* enzymatic processes. Again, we cannot all possess an ultramicroscopic equipment, yet there should be such equipment accessible at convenient points.

There are few of us who cannot appreciate the value of special conferences and of contact with one another in groups at meetings such as those we are holding here this week. I feel certain that the idea of special conferences modified to meet particular needs, could be greatly extended as a factor in effective research. The promotion of contact between investigators in large groups has its limitations. Even so, however, such contact has been possible for a considerable class of biologists (including physiologists) at the Marine Biological Laboratory and, for smaller numbers, at a few other—mostly marine—laboratories in the country. The Desert Botanical Laboratory has offered special advantages to a limited number, and this type of opportunity is just what is desired. It appears to me, however, that there are too few continuous or discontinuous influences of this type for groups of botanists. My idea is that extended conferences, or team-work investigation—real democratic team work, often occupying much of the summer vacation, arranged by relatively small groups of workers interested in related problems, would bring results at a minimum of effort. Indeed, I feel sure that some of the problems confronting our experiment stations could be most efficiently and even cheaply solved by arranging for properly selected group work of this type. I do not refer to that kind of team work in which there is one dictator and many mechanicians, although that may be good enough at times.

Related to these suggestions, there is particular need of fostering the laboratory encouraging worthy post Ph.D. research, or offering favorable contact for the man on sabbatical leave, and this, I believe, is a thing to be striven for by several of our labora-

tories devoted entirely or primarily to research and graduate work.

Theoretically we doubtless admit the necessity of close coöperation between the departments of plant physiology on the one hand and those of chemistry and physics on the other. In our universities and colleges apparently this is not developed to the same extent that it is in England, for one can seldom pick up an English journal containing an important contribution in physiology which does not exhibit and acknowledge the closest coöperation with the department of chemistry or of physics of the same institution. This to my mind accounts in some degree for the very high standard of work which has been done in England in recent years. We saw it in the work of Marshal Ward some fifteen to twenty years ago, and we see it today in that of various investigators who occupy prominent positions. I fear that we have not yet yeached the point where we are willing to lay the cards on the table, as it were, in order to secure the assistance of our colleagues in other fundamental sciences.

Nevertheless, I do not forget that fundamental research generally means individual effort, but there are times when no individual can adequately encompass the problem which he faces. Whatever may be said about physiology as merely a special phase of physics and chemistry, we who are in the subject know that it is in reality much more than that, and it is scarcely possible for one man to be in all phases and at once a broad physiologist and a thoroughly competent biochemist and biophysicist. Surely, then, the University with its varied departments should promote coöperative effort. But for some reason special institutions with "topical problems" rather than highly specialized departmental research seem to be those who are successfully and chiefly doing coöperative work.

As to publication, one needs to look back scarcely ten years to the time when the main sources of publication for plant physiological and pathological materials were the Botanical Gazette and the Torrey Bulletin, aside, of course, from a few proceedings of societies and the popular bulletins of the agricultural experiment stations and the department at Washington. Today there are

not less than fifteen journals or periodicals of high grade, in which material of this type finds ready publication—and this is exclusive of the sources of publication already referred to. In addition there are the technical bulletins of the various experiment stations and several chemical journals to some of which plant physiological material at least finds ready access. That the establishment of these journals indicates extraordinary progress, and that their maintenance on a high plane tends constantly to stimulate the best grade of work and to discourage unfaithful work, scarcely needs argument. Possibly though we have already gone too far in this matter of number of periodicals. American chemists—although perhaps quite ten times as numerous as all botanists—have only five or six distinctively chemical and biochemical periodicals. We need data, especially quantitative data, but diffuse publication does not foster research. The number of physiological titles which appear in American literature in 1900 gathered from various abstract journals, and from a careful study of American journals—was scarcely a baker's dozen, while the number for 1918, in spite of war conditions, is estimated to be not less than one hundred and fifty. In spite of this progress, however, and of the integrity of present day motives, we realize more than ever that we are on examination before the world, and that the quality of the work should rise with the responsibilities which confront us. I believe that ultimately no factor will contribute more to the confidence and success of American botanical research than a well-edited world-circulated abstract journal, and to my mind it is the first duty of every American botanist to support this enterprise. We have not as yet made more than a beginning towards an adequate expression of American research work in the form of monographs, or topical handbooks, and once our abstract journal is well established, I anticipate relatively little difficulty in the publication of such scientific memoirs.

In bringing this discussion towards a conclusion I wish to treat one phase of research more specifically. I am so impressed with the desirability of joint effort that I wish to mention four problems in which I am interested that seem to offer special oppor-

tunity. (1) Nutrition of the fungi, (2) solution requirements of green plants, (3) "mosaic" diseases, and (4) the role of colloids in the water relation of the cell. I desist from outlining the problems or indicating their present status, except in two instances, and these are the last two mentioned. The first is a problem on the borderland of physiology and pathology. For years the question of filterable "viruses" has been one of great importance in animal pathology, and it has also received considerable attention from the plant side, necessitated by the economic significance of such diseases as the mosaic diseases of tobacco, peach yellows and little peach. On the whole the "organism" theory is most generally accepted in the case of the twenty odd human and animal diseases listed as belonging to filterable viruses. There is apparently no unanimity of feeling as to how organisms could exist, with organization and extensive correlation, possessed of the size which many of these have been assumed to have, as indicated by filtration relations. In a very few cases only have cultures presumably been secured; that is, in practically all cases the organism has not been seen, even in mass. In the great majority of cases no characteristic of an organism has been demonstrated further than the capacity of the virus to reproduce itself (an important character, certainly) when introduced into a healthy host organism. Nevertheless, there is wide variation in the degree of infectiousness or contagiousness of the different diseases. On the plant side there is convincing evidence that in the case of yellows it is essential that budding or some other tissue transplanting method be employed in order to insure infection by known means. The mosaic diseases stand in direct contrast, since here the juice of affected plants is highly infectious. New York and other northern states expend annually a considerable sum of money on inspection work in the hope of eradicating the yellows. I have spent parts of several summers in the peach yellows district and I have been able to see no indication that the disease is being "eradicated." Of course, there is much less yellows than when inspection began, which is due in part to uprooting the affected trees. The disease runs its course in about three years and the average man sees less yellow today because

of the fact that it never reaches the stage when it is evident to those not cognizant of the early symptoms. There exists no experimental proof that the disease may be conveyed by infected soil, by contact with diseased trees, by the action of insects or by pollination.

It is conceivable that all of the diseases mentioned might be induced by chemical substances provided we assume that any chemical body may have the power of stamping upon the protoplasm the capacity of regenerating itself. This is perhaps the one strong criticism against the enzyme or chemical theory of cause. Nevertheless when we consider how little is known regarding the cell activities resulting in the production of enzymes, how elemental is our knowledge regarding their production as influenced by the substrate, how complex and difficult are the anaphylactic relations in animals and lastly how mysterious the influence of iron in the cell is upon the production of chlorophyll, we can see at least the possibilities of new lines of research in the case of these so-called physiological diseases. I do not mean at all to imply that there are not ultra-microscopic organisms. Ultra-microscopic organisms, however, must exhibit metabolic functions other than those of propagation, and when they may be obtained in relatively high concentration in body fluids and in plant juices we should have some proof of their metabolic activities, of their respiration.

I feel that research in these directions has been curtailed by the assumption that any such "organisms" exist, when the proof of it should be possible, and should be furnished by those who maintain their existence. If such organisms exist, it is clear that they are not of widespread distribution, and perhaps do not occur at all as saprophytic organisms, otherwise we should have encountered them in the various fermentative processes characteristic of plant and animal products. We are making an effort to study the metabolism of such assumed organisms. Many difficulties beset the investigator and there is no problem known to me in which wider skill in the methods of bacteriology, biological chemistry, and colloidal chemistry are required. A group of investigators attacking such a problem and conferring in

respect to their progress would seem to be a most feasible and laudable association of interests.

Lastly, in reference to particular problems, I may refer to the water relations of cell or tissue as governed by diffusion and colloidal hydration. On present information the plant physiologist may have no idea of discarding the role of osmotic pressure in the cell, but it is to be inferred that he is in full sympathy with the proper evaluation of this factor, and he could well join forces with the physical chemist to examine critically and in a new light all factors involved.

In conclusion let me say that the time has long passed when adequate training for physiological and pathological investigation is obtainable through a botanical or a general biological groundwork, since broad fundamental chemical preparation is particularly essential. This is true whether the ultimate direction of the physiological research pursued is toward the ecological side or the chemical side. No less consideration should be given to chemical preparation than to botanical preparation and it would be a great step forward if departments of botany as a whole acceded to this. If it is not recognized the task of the teacher in training investigators in physiology is too great.

A COMPARISON OF THE VEGETATIONAL FEATURES OF TWO DESERT MOUNTAIN RANGES

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In southeastern Arizona and southwestern New Mexico there are a number of forested mountains which are separated from one another by desert plains and valleys. The irregular plateau upon which these mountains stand is a portion of the continental divide, draining westward into the Gila River and eastward into the Rio Grande. The greater part of the so-called plateau lies between 3000 and 5000 feet in elevation, being in fact the lowest part of the continental divide between northern Canada and the Isthmus of Tehuantepec.[1] None of the mountains exceed a length of 25 miles, but many of them lie in broken chains, usually running in a NNW-SSE direction and connected by low hills or narrow passes. Immediately south of the group of mountains under consideration lies the northern end of the Sierra Madre Occidental, which forms the boundary between the states of Sonora and Chihuahua, and north of the group are the White Mountains and the Mogollon Mesa, which form the southern edge of the Colorado Plateau. Far to the northeast lies the southernmost portion of the Rocky Mountains, in northern New Mexico.

It is only on the mountains which exceed 7000 feet in elevation that forested areas are to be found, although lesser elevations are frequently occupied by low or open woodland. The principal mountains in the group under consideration are: Baboquivari, Santa Catalina, El Rincon, Santa Rita, Huachuca, Pinaleno, Chiricahua, Las Animas and San Luis. Among the

[1] The Southern Pacific Railroad crosses the continental divide near Separ, New Mexico, at 4502 feet, and the El Paso and Southwestern Railroad crosses it near Vista, New Mexico, at 4679 feet.

less heavily forested mountains are the Whetstone, Mule, Swisshelm, Dragoon, Galiuro, Dos Cabezas, Peloncillo and Big Hatchet ranges. The highest of these mountains is the Pinaleno range, which lies near the left bank of the Gila River at Safford, Arizona, culminating in Mt. Graham at 10,550 feet.[2]

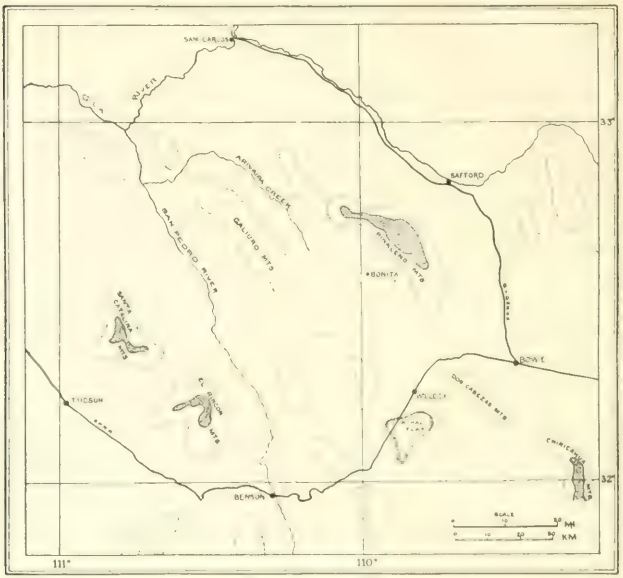

Fig. 1. Map showing the location of the Pinaleno and Santa Catalina Mountains and adjacent ranges.

After several season's work in the Santa Catalina Mountains the writer became interested in making an examination of the Pinaleno range with a view to comparing the general vegetational and floristic features of the two. A comparison of these moun-

[2] This range is locally known as the Graham Mountains, through a careless use of the name of the highest peak as a designation for the entire range.

tains is made more simple than might be the case by the fact that they are both in a relatively initial stage of physiographic development, are both built chiefly of gneiss and both lie in a WNW ESE position. It is possible, therefore, to compare the vegetation at the same elevations in the two mountains with a minimum of complicating features, and to determine the influence of the greater altitude of the Pinaleno range in affecting the character of its vegetation and flora. In making such a comparison it is necessary to take into account the universal influence of slope exposure, and also the influence on vertical distribution which is invariably exerted by the elevation of the surrounding country.

The Pinaleno Mountains may be pictured as a series of rolling areas surrounded on all sides by steep ridges and narrow cañons, falling away to the flood plain of the Gila on the northeast and to the Bonita, or Sulphur Spring, valley on the southwest. The length of the range is about 28 miles if we disregard the chain of foot-hills that stretches southward toward the Dos Cabezas range. Some of the most salient physical features of the mountain are determined by the fact that on its northeastern side its drainages reach the Gila at elevations of about 2600 feet, and on the southwest side its streams fall to the Bonita valley at only 5000 feet. On the side of the mountain facing the Gila River steep alluvial fans, or bajadas,[4] have been deposited. All of the large streams have cut through these bajadas so that their upper courses now lie through rocky cañons with V-shaped bottoms and their lower courses through shallow cañons in the outwash material, with broadly U-shaped bottoms. A section of one of the bajadas cut parallel to the face of the mountain would exhibit a level top with pronounced edges and sides falling away in parabolic curves. The average distance from the Gila River to the true base of the mountain is about 6 miles. The longest

[3] The vertical limits of species and of vegetations are different on mountains of different mineralogical character. In general, desert species reach higher elevations on volcanics than on gneiss and the highest elevations on limestone.

[4] This Spanish word, which has been quite generally adopted into the vocabulary of physiographic terms, should be pronounced *bahátha*.

of the bajada slopes extend to within 3 miles of the river, and in many cases their slender ends have been cut away from the main bajada, now appearing as elliptical hills with steep sides and flat tops, which still show an inclination accordant with that of the main bajada (see fig. 2). The inclination of the bajada surfaces is such that the innermost portions, next the mountain, are about 1000 feet higher than the ends nearest the river. The gradient of the streams as they follow the interbajadal valleys is much less than this. The line of contact between the true base of the mountain and the summits of the

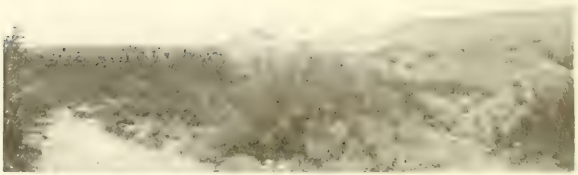

Fig. 2. Looking toward the Gila River from the southeastern base of the Pinaleno Mountains, showing the dissected bajada at the right, and in the center a hill of bajadal origin.

bajadas is now almost invariably occupied by shallow drainageways of relatively recent origin, or in a few cases is occupied by a major streamway.

On the southwestern side of the mountain the largest streams reach the plain and quickly disappear, with almost no evidences of the history of the enormous amount of deposition that must have been taking place. There is abundant evidence that these streams have frequently changed their courses in the immediate vicinity of the mouths of their cañons, but the boulder-strewn

deltas over which this vacillation has taken place are only very slightly elevated above the adjacent plain.

The plain at Bonita is a portion of the Sulphur Spring Valley, which has a total length of about 100 miles in the United States, a width of 10 to 25 miles, and lies wholly above 4000 feet. The central part of this valley is a bolson, or enclosed basin, draining into an extensive alkali flat, which is crossed by the Southern Pacific Railroad between Willcox and Cochise, Arizona. The southern portion of the valley is drained by the Whitewater Draw and the northern portion by Arivaipa Creek, a tributary of the San Pedro, which is in turn a tributary of the Gila. The Arivaipa is a small stream fed only by storm waters, and its upper course lies through an alluvial valley from one to two miles in width. This valley is sharply separated from the older and higher level of the Sulphur Spring Valley by a low scarp. Although the Arivaipa is thus seen to be working in the direction of the ultimate tapping of the Willcox bolson, it is nevertheless doing so at an extremely slow rate because of the small volume of its flood waters. The great difference which has been described as existing between the basal topography of the two sides of the Pinaleno Mountains is undoubtedly due in great measure to the presence of the strong drainage of the Gila on the one side and the weak drainage of the Arivaipa on the other, if we disregard the original structural characteristics of the region.

VEGETATION

The larger features of the vertical distribution of vegetation in the Pinaleno Mountains are similar to those that have been described by the writer for the Santa Catalina Mountains,[5] The outstanding features of dissimilarity between the two mountains are due to the greater altitude of the former (by 1400 feet), and to the fact that the cañons of the former are more sharply cut and better watered. The higher elevation results in extended areas of forest of a type which is only spar-

[5] Shreve, Forrest. The vegetation of a Desert Mountain Range as Conditioned by Climatic Factors. Carnegie Inst. Wash. Pub. 217, 1915.

ingly represented at the highest altitudes in the Santa Catalinas. The rugged topography of the Pinaleno range and the numerous constant streams bring about a sharper contrast between the vegetation of cañons and slopes at lower and middle altitudes than is the case in the Santa Catalinas. The evergreen scrub of lower altitudes is carried to high elevations on the steep south slopes and the mesophytic vegetation is carried to low elevations along the constant streams of the larger cañons. This sort of interdigitation of the lowland and mountain vegetation is conspicuous in all desert mountains, but its amplitude is greater in the Pinaleno Mountains than in any of the smaller neighboring ranges.

The narrow belt of desert which lies between the Gila River and the eastern base of the Pinaleno Mountains is characterized mainly by *Corillea tridentata*, *Atriplex polycarpa* and *Lycium gracilipes*. The commonest representatives of the cacti are *Opuntia stanlyi*, a low form with club-shaped joints, and *O. engelmannii*, an erect platyopuntia with very large joints. The simple vegetation of the desert floor becomes somewhat richer on entering the interbajadal valleys, where *Prosopis*, *Atriplex canescens* and *Isocoma wrightii* are the most abundant plants. *Opuntia spinosior, O. engelmannii* and *O. macrocentra* are the only common representatives of the cacti in these valleys and on their gravelly sides. In habitats of this character at elevations only 800 feet lower in other parts of southern Arizona there is a strong representation of such striking cacti as *Carnegiea* and *Opuntia bigelorii* and a series of desert shrubs and perennials confined to lower elevations.

The tops of the largest bajadas lie between 4000 and 5000 feet, sloping upward at a gradient of slightly less than 500 feet to the mile. The extremely coarse material of which they are built is revealed by their gravel soil and numerous rounded boulders of 1 to 4 feet in diameter. The southern crests of the bajadas are thickly clothed with the common species of *Opuntia* and with *Fouquieria*, while the tops are very scantily covered with *Prosopis* and *Yucca radiosa*, and with a very open summer carpet of *Hilaria cenchroides*, *Eragrostis lugens*, *Aristida schiedeana*,

the omnipresent *Gutierrezia gracilis* and other herbaceous plants. On the portions of the bajadas nearest the mountain and on the north-facing slopes at 4800 to 5200 feet the shrubbery becomes more abundant, being open on the level and forming closed thickets on the slopes. The characteristic shrub is *Quercus grisea*, and almost equally common are *Ceanothus greggii*, *Cercocarpus paucidentatus*, the semi-succulent *Nolina* and the suffrutescent *Artemisia ludoviciana*. Less frequent are *Juniperus monosperma*, *Garrya wrightii*, *Arctostaphylos pungens* and *Agave parryi*.

Fig. [illegible] Slopes of Frye Canon, on the northeast face of the Pinaleno Mountains, showing encinal with scattered individuals of *Pinus chihuahuana*.

At the altitude of the uppermost portions of the bajadas it will be found that the interbajadal valleys and the cañons of the mountains itself are heavily wooded with evergreen oaks, with *Juglans major* and *Platanus occidentalis* along the streams. At elevations as low as 5500 feet, and near the banks of constant streams, it is possible to find numerous shrubs and other plants characteristic of higher altitudes, such as *Robinia neomexicana*, *Quercus submollis*, *Alnus oblongifolia*, *Ceanothus integerrimus* and *Salix* sp.

After reaching the slopes of the mountain proper we find a typical encinal[6] in which *Quercus emoryi* and *Q. arizonica* occur along with the components of the scrub just mentioned. Communities of this general composition occupy the south-facing slopes up to 7000 feet, and a scrub of similar appearance clothes the steepest slopes of southern outlook to elevations of slightly more than 8000 feet. *Cercocarpus* and *Robinia* are among the few shrubs that range throughout the vertical extension of the encinal and its high-altitude analogue. Above 7000 feet this shrubby vegetation is made up chiefly of *Quercus reticulata*, *Q. submollis*, *Q. hypoleuca* and *Ceanothus fendleri*. At its highest limit it is sometimes found to merge into young thickets of *Populus tremuloides*.

On the southwestern side of the Pinaleno Mountains the vegetation is much more simple in its distributional features, owing to the greater simplicity of the topography. The grassland of the Bonita valley becomes very open as it is followed up the slopes immediately adjacent to the base of the mountain, and *Yucca radiosa* is the most conspicuous of the woody plants, with *Opuntia spinosior* and *Prosopis* playing a secondary rôle. Open encinal covers the lowest slopes of the mountain, here somewhat more than 5000 feet in elevation, and descends in many places onto the gentle alluvial aprons over which the principal streams find their way to the plain. The courses of the largest streams, as those from Grant, Goudy and Jesus cañons, can be traced from a distance by their trees. These are chiefly *Quercus emoryi*, *Fraxinus velutina*, *Platanus occidentalis* and *Juglans major*. Near Fort Grant a running stream ten feet wide may be found at all seasons of the year, shaded by its fringing grove of trees. On following this stream down the very gentle slope toward Bonita the amount of water is found to become rapidly less and the riparian grove to become more and more open. Within less than two miles from the mouth of the cañon the water has vanished and the dry streamway has

[6] Encinal is an open or closed community in which evergreen oaks are dominant. From the Spanish *encina*, evergreen oak; *encinal*, evergreen oak forest. (Pronounced with accent on the last syllable.)

a marginal growth of *Yucca*. The large triangular area which receives this natural and continuous sub-irrigation from the waters of Grant and Goudy cañons has been the seat of successful agricultural operations from the earliest settlement of Arizona.

The extent of pine forest in the Pinaleno Mountains is not so great as might be expected from the size and altitude of the range, owing to the extremely steep and rocky character of the slopes that lie at favorable altitudes for the pines. The total area of forest is about 56 square miles, if we comprise the encinal and brushland that lies above the normal lower limits for the

Fig. 4. A park on the main ridge of the Pinaleno Mountains at 9200 feet surrounded by forest of *Pinus ponderosa*. The park is chiefly occupied by *Dugaldea hoopesii*.

pine. The total area of the mountain lying above 8000 feet is slightly over 35 square miles, and this is almost completely covered with forest.[7] Out of the 21 square miles of forest or potential forest below 8000 feet it is doubtful if the pines occupy more than 8 to 10 square miles, whereas they occupy scarcely more than this much of the heavily forested area above 8000 feet, where other trees are dominant.

[7] I am indebted to Mr. T. T. Swift, Supervisor of the Crook National Forest for the loan of maps of the Pinaleno Mountains from which these computations of area were made.

On the northeast face of the mountain the pines are first encountered at about 6800 feet, while on the southwest face there are very few groves below 7600 feet. This difference is partly due to slope exposure and partly to the well-known influence which is exerted on the vertical distribution of mountain vegetation by the elevation of the basal plain or valley. Extensive areas between 7000 and 8500 feet are occupied by oak scrub, with groves of pines only in the most favorable situations.

The predominant pine is *Pinus ponderosa*. The closely allied form known as *Pinus arizonica* has not been detected in the

Fig. 5. Forest on a shoulder of the north slopes of Mt. Graham at 10,300 feet. [illegible] *Pinus ponderosa*, *Pinus strobiformis* and *Abies concolor*.

Pinaleno Mountains, although in the Santa Catalina range it forms the great bulk of the yellow pine forest, *Pinus ponderosa* being local and infrequent. Above 8600 feet the pines are confined to southern exposures and at about 9500 feet they reach their upper limit. The northern slopes between 8000 and 9500 feet are chiefly occupied by *Pseudotsuga taxifolia*, *Abies concolor* and *Pinus strobiformis*, all trees of general occurrence throughout the high mountains of southern Arizona. On going above 9600 feet these trees become less frequent. The highest elevation is reached by *Pinus strobiformis*, which occurs on dry ridges at 10,300 feet, where its resemblance to *P. flexilis* is very strong.

The low dense forest found on the main ridge and at the summit of Mt. Graham, from 9600 to 10,500 feet is made up of *Picea engelmannii* and *Abies arizonica*. Neither of these trees is found elsewhere in the isolated mountains of southern Arizona except for the occurrence of a small colony of the latter on the north slopes of Mt. Lemmon in the Santa Catalina range. Other woody plants characteristic of the *Picea-Abies* forest are *Salix bonplandiana*, *Populus tremuloides*, *Alnus tenuifolia*, *Symphoricarpus oreophilus*, *Lonicera involucrata*, *Vaccinium scoparium* and *Rubus parviflorus*.

RAINFALL

In the summer of 1917 the writer attempted to secure a series of rainfall readings at 1000-foot intervals on the southwest face of the Pinaleno Mountains, for comparison with a similar series

TABLE 1

Rainfall for the summer of 1917 in inches

	SANTA CATALINAS, JUNE 26TH-SEPTEMBER 30	PINALENOS, JULY 6TH-SEPTEMBER 30
Tucson, 2400 feet	6.26	
Thatcher, 2800 feet		2.62
3000 feet	6.1	
4000 feet	8.0	
Willcox, 4190 feet		6.07
Bonita (4916 feet)		5.75
5000 feet	7.1	
6000 feet	9.2	12.0
7000 feet	14.0	15.5
8000 feet	15.0	13.0
9000 feet	17.3	12.1

in the Santa Catalinas. Five metal cans were installed from 6000 to 10,000 feet inclusive, with 8 liters capacity and 10 cc. of kerosene to prevent evaporation. The gauges were installed and read on both mountains at such time as to secure the summer rainfall alone (July, August, September). The gauge at 10,000 feet was overturned during the summer and the record lost. The readings for the other stations on the two mountains, together with those for the Weather Bureau stations at adjacent towns are shown in table 1.

It goes without saying that the rainfall record of a single season is of relatively little value, but it has been impossible to continue the observations on the Pinalenos and the data secured are of too great interest to be discarded. The altitudinal curve for the Santa Catalinas (fig. 6) closely approximates the form of the average curve for a ten-year series in that mountain, showing a sharp rise from the base, at 3000 feet, to the first mountain station, at 4000 feet, a drop to the second station, at 5000 feet, and a pronounced rise from 6000 to 7000 feet. There have been several years when the rainfall at 9000 feet on the Santa Cata-

Fig. 6. Canopy of the forest on the summit of Mt. Graham at 10,500 feet. The trees are chiefly *Picea engelmannii*.

linas was less than at 8000 feet, and the question rose as to whether 9000 feet was near the elevation at which the altitudinal increase of rainfall ceases in this region. The aim of securing data from the Pinalenos was (1) to determine whether the altitudinal increase of rainfall has ceased at 10,000 feet; (2) to determine the influence of the higher basal elevation of these mountains in affecting the shape of the curve of altitudinal increase; and (3) to discover whether the lowest station in the forest has here a markedly higher rainfall than the next station below it, as is true in the Santa Catalinas.

The answer to the first of these problems was not wholly lost by the failure of the record at 10,000 feet, as the maximum rainfall was registered at 7000 feet and there was a progressive fall up to 9000 feet, this station having nearly the same reading as the one at 6000 feet. In 1917 the rainfall at Bonita, near the

Fig. 7. Graphs showing the relation of altitude to rainfall in the Santa Catalina Mountains (heavy line) and Pinaleno Mountains (light line) for the summer of 1917.

base of the Pinalenos, was slightly less than at Willcox, 35 miles away near the centre of the bolson, although Bonita is nearly 1000 feet higher than Willcox. At the first mountain station, however, the rainfall was more than twice as great as the fall

at Bonita, showing that here, just as in the Santa Catalinas, the first 1000 feet of mountain slope engender a marked rise in the rainfall. The conditions which give the forested elevations of the Santa Catalinas a much higher rainfall than the encinal region appear to be reversed in the Pinalenos, where there is a fall in the precipitation on ascending from the latter vegetation at 7000 feet into the forest at 8000 feet.

The vertical distribution of rainfall in the isolated mountains of the southwest is not only of great theoretical interest to meteorology but is of fundamental importance in connection with our knowledge of their vegetation, and also of practical value to foresters with relation to forest management and the control of fires. Any seasonal records that can be taken will be of great value, as it will obviously be a long time before we can secure data for the entire year at these uninhabited elevations.

FLORA

At the present time the floristic features of the Pinaleno Mountains can be discussed only in a general way. The imperfect knowledge of their flora may be judged by the fact that no plants were collected in them after the visit of J. T. Rothrock, with the Wheeler Expedition in 1874, until the first visit by the writer in 1914. The most prominent differences between the forested elevations of the Pinaleno and Santa Catalina Mountains lie in the existence of a group of subalpine species in the former, for which there are no favorable altitudes in the latter; and in the existence of a few species at lower elevations in the former which have failed to make their way to the latter. The Pinaleno Mountains are also without many of the desert and encinal species of the Santa Catalina Mountains.

The most prominent of the subalpine plants found in the Pinaleno range but absent from the Santa Catalinas are:

Alnus tenuifolia Nutt.
Caltha leptosepala DC.
Campanula parryi Gray
Chimaphila umbellata (L.) Nutt.
Gentiana [illegible] A. Nels.

Ibidium strictum (Rydb.) House
Ligusticum porteri C. & R.
Lonicera involucrata Banks.
Mertensia pratensis Hell.
Oreochrysum parryi (Gray) Rydb.
Pachistima myrsinites (Pursh) Raf.
Pedicularis grayi A. Nels.
Peramium decipiens (Hook.) Piper
Picea engelmanni Parry
Potentilla diversifolia Lehm.
Rubus parviflorus Nutt.

All of these 16 species are found in the mountains of New Mexico and Colorado and 11 of them range northward as far as British Columbia.

A few plants are found in the forested elevations of the Pinaleno range below 9000 feet which are not known from the Santa Catalina Mountains. This group is to be distinguished from the former by the fact that all of its members are growing at elevations which exist in the latter mountains, and they do not therefore appear to depend upon physical conditions which exist only above the altitude of the highest point in the Santa Catalina range.

Berberis repens Lindl.
Ceanothus integerrimus H. & A.
Erysimum wheeleri Rothr.
Galinsoga parviflora var. *semicalva* Gray
Pericome caudata Gray
Rhamnus latifolia Greene
Thermopsis pinetorum Greene
Veronica serpyllifolia L.

All of these species are common at their appropriate elevations and in their particular habitats.

A few species are found above 8000 feet in the Pinaleno Mountains which have also been detected in the Santa Catalina range. All of this group are common and widespread in the former and found only in one, two, or in one case in three very restricted localities in the latter. They are:

Abies arizonica Merriam
Acer glabrum Torr.
Artemisia franserioides Greene

Lonicera arizonica Rehd.
Parthenocissus vitacea (Knerr.) Hitchk.
Ptelea angustifolia Benth.
Vaccinium scoparium Leiberg

Each of these lists will undoubtedly be greatly extended by further exploration. To the last of them, however, there attaches an importance which has no relation to its length. Each of the species listed as local in the Santa Catalina range is found in only a small portion of a particular area over which the physical conditions are identical, and over which the species characteristic of that area are found to recur constantly. Each of these seven species is common in the Pinaleno Mountains and found throughout its particular altitude and habitat. It is to be expected that each of them will gradually spread in the Santa Catalinas until all of them are likewise coextensive with a particular set of limiting conditions. We are here brought to face with the entire problem of the manner in which the isolated desert mountains received their plant population. This problem is a large and difficult one, on which the evidence is at present extremely meagre. There seems to be no evidence, however, in favor of such a radical change of climate within the life of these mountains as to have brought about a continuous lowland vegetation like that which is now confined to the mountain summits. In other words we can not think of the forest flora as having been derived by the retreat up the mountains of a forest which formerly occupied the desert valleys. The floristic evidence is against such a view, and is such as to indicate that the isolated mountain forests have secured their plant populations by some means of dispersal across the arid areas which lie between them and the mountain masses to the north-east and the south-east.

The means by which such dispersals took place were undoubtedly numerous, and the rate at which they operated was probably very slow. The limited area of the mountain tops has in itself been an important factor in making this process a slow one. In the Pinaleno Mountains there are 35 square miles above 8000 feet in elevation, in the Chiricahua Mountains 25 square miles and in the Santa Catalinas only 5 square miles. In the last named

range the total length of all the constant streams above 8000 feet is only 1.5 miles. The very moist soil along these streams is the only habitat for over 25 species of plants. Making a generous allowance of 5 feet as the average width of the moist soil along the streams, we have a total of 39,600 square feet, or slightly less than one acre. Even if we hypothecate that most of the dispersal from mountain to mountain has been by the agency of birds, and that the plants growing in moist situations above 8000 feet have been distributed by birds which chiefly frequent that habitat, we have nevertheless a case in which the chances for invasion are rendered extremely poor. This case is scarcely more extreme than others that might be mentioned, and it is cited as bearing on the rate at which invasion by new species has probably been taking place.

The vegetational differences between the several desert mountain ranges are relatively simple, and may be interpreted in terms of the differences in physical conditions which are brought about by differences in altitude, in basal elevation, in character of rock and other features. The floristic differences between them indicate a secular movement of species from the larger and more elevated mountain masses toward the smaller and more isolated ones, with a rapid impoverishment of the flora as the latter are approached.

BOOKS AND CURRENT LITERATURE

Sugar Metabolism in Cacti. In a recently published monograph Spoehr[1] presents and discusses the results of some scores of analyses of cacti subjected to various natural and experimental conditions. The monograph is much more than a summary of analytical data. The causes and results of the changes in carbohydrate content and in the ratios of the individual carbohydrates to each other would follow the seasons, the water-balance of the plant, the temperature, the external food supply and the respiratory activity are discussed most suggestively but with results which it is impossible to review in detail without repetition of the comprehensive chemical data.

The feature of the results which seems to the reviewer of greatest present interest is the role of the pentose sugars, a matter already noted by Spoehr in these columns.[2] These compounds, which are differentiated from the ordinary or hexose sugars by having their carbon atoms arranged in groups of five instead of six, are represented in plants mainly by the pentosans,—complex polysaccharids which are the gums or mucilages present in many vegetable cells. These mucillages are prominent in the cacti and Spoehr has shown that they may be consumed, on occasion, in the metabolism of the plant. Furthermore, it appears that conditions of low water supply favor the formation of these pentosans in the cell, and this suggests a possible mechanism for the production of large, mucilaginous cells, and therefore of succulent habit, as a response to dry conditions.[3] The great capacity of these gums for the imbibition of water, with the resultant swelling, gives them important place in the colloidal changes which accompany growth.[4] The known presence of pentose sugars in the nucleus of the plant cell completes the picture of a group of carbohydrates probably

[illegible]
Pub. 287, 79 pp., 1919.

[2] The Plant World, **21**: 365–379 (1917).

[illegible]
Bot. Gaz. **67**: 405–416 (1919), and MacDougal and Spoehr, "The origination of xerophytism,"—The Plant World **21**: 245–249 (1918).

[4] See MacDougal and Spoehr, "Growth and imbibition,"—Proc. Amer. Phil. Soc. **56**: 289–352 (1917).

destined to play a significant rôle in the metabolic and protoplasmic theories of the next decade.

As indication of the general carbohydrate composition of the material used by Spoehr portions of two analyses may be quoted; one of *Opuntia phaeacantha*, which is a mucilaginous species; the other of *Opuntia versicolor*, which is less so.[5]

Water	78.70	82.15
Total sugars	3.53	1.97
Total hexose sugars	1.81	1.59
Total pentose sugars (including pentosans)	1.64	0.36
Pentosans	1.55	0.23

The monograph contains detailed descriptions of the analytical methods employed for the extraction and clarification of the plant juices and for the separation and determination of the hexose and pentose sugars. The specialist will find these of value. Such more general readers as resemble the reviewer in being a little hazy concerning the exact relationships and behaviors of the numerous sugars which are now known will thank Spoehr for his clear and comprehensive Introduction, a chapter well suited to introduce not only this particular monograph, but sugar metabolism in general. E. E. Free.

A New Economic Botany.—Under the title "Applied Economic Botany,"[6] a new botanical text is presented in the Farm Life Series, which, according to the preface, is needed because of poorly adapted books on the market. With the statement regarding the adaptability of texts already in use, the reviewer does not entirely agree. Most of the complaints against our present texts in botany, if investigated, would not be scored against the books, but against the teacher. If fewer botanical classes in secondary schools were taught by latin, history and chemistry teachers, there would be fewer complaints against textbooks. With another of the author's statements however, few will disagree. Undoubtedly the secondary schools are trying to cover too much ground instead of limiting their field to fundamentals. This again is the fault of the teacher. It is doubtful if any text will really hold such instructors in check.

[5] Data selected by the reviewer from table 8, page 40 of the monograph.

[6] Cook, Mel. T. Applied Economic Botany. 1919.

Applied Economic Botany contains eleven chapters on the structure, physiology and ecology of angiosperms; one chapter each on the gymnosperms, pteridophytes and bryophytes; two chapters on the thallophytes (including bacteria); one each on forestry, plant diseases, plant breeding and weeds; one on important families of economic plants, and one on special exercises (additional study of economic plants). The first four chapters take up seeds and the vegetative organs of the mature angiospermous plant. The student is introduced to enzymes early in the course in connection with the germination of seeds. Roots, stems, leaves and flowers are treated in a manner similar to that used in the Gray botanies. In the chapter on plant foods and plant growth, the paragraph on "circulation" might have been incorporated with that on "transfer of water," thus avoiding a misleading term. Although cells are constantly referred to in preceding chapters, the student first takes up the topic of cellular structure in the eighth chapter. Plant diseases are discussed before either fungi or bacteria. Gymnosperms are isolated from pteridophytes by chapters on forestry, plant breeding, plant diseases and weeds. Ferns are treated without reference to alternation of generations, although a diagram of the life history is given,—but perhaps such a reference is incompatible with economic botany or applied botany. *Spirogyra* is somewhat removed from the exalted position occupied in many secondary school texts as the "type" of green algae, a fact to the credit of the text, although it remains one of the two green algae figured. The statement that "a large number of free-swimming cells known as zoospores" are produced in *Ulothrix*, and that "in some cases these free-swimming cells (gametes) unite in pairs and form zygotes," is not likely to be very clear to the ordinary high school student (or teacher either) without further explanation.

In the glossary we learn that an antheridium is "the organ in cryptograms corresponding to the anther in flowering plants," and the archegonium is "the organ in cryptograms corresponding to the pistil of flowering plants." Such inaccuracies are inexcusable, even in an elementary text.

Although the author states that he has been mindful of the needs of "those who study it (botany) as a cultural subject," such topics as Mendel's Law, which can be presented in an elementary way in a perfectly intelligible form for secondary school students, and has been so presented in other tests; alternation of generations; and response to environment, are either omitted or are referred to in such a casual way that they might as well have been left out.

In conclusion the reviewer believes that the sequence of the chapters could have been made more logical; that several subjects treated in the text could have been somewhat amplified to the greater value of the book and without danger of presenting unnecessarily detailed description for secondary school students; that greater accuracy would have been desirable; and that the needs of general culture students are overlooked to a great extent.—J. G. Brown.

NOTES AND COMMENT

H. M. Hall and Joseph Grinnell have published in the Proceedings of the California Academy of Sciences a paper on Life Zone Indicators in California. A brief preliminary discussion is given of some of the conditions which cause nature to depart from the life zone arrangement of organisms in certain localities. Lists of plants, amphibians, reptiles, birds, and mammals are given for each of the zones from Lower Sonoran to Arctic-Alpine. The plant lists are confined to perennials and are chiefly made up of trees and shrubs.

The publication will be of some use to students of plant and animal distribution in California, but it does nothing to give the "life zone concept" a more logical basis than it possessed before. An organism that is supposed to be an indicator of the existence of a particular set of environmental conditions, fluctuating between certain extremes, should presumably be in great part coextensive with these conditions. If it is not we are left in the position of wondering what is indicated by the indicator. Even in bringing together a list of organisms which are collectively indicative of the existence of a particular gamut of conditions it is difficult to see the force of including species of very restricted range. For example, the authors have listed *Pinus radiata*, *Cupressus macrocarpa* and *Sequoia gigantea* as indicators of the Transition Zone in California.

The life zone concept is not designed to add anything to our knowledge of the causes underlying distributional phenomena, and if every organism growing locally within a zone is to be regarded as an indicator of the zone, the concept will lose its value even as a mere scheme for placing distributional facts in convenient pigeon holes.

Dr. S. S. Visher has published a report on the Geography of South Dakota, as Bulletin 8 of the South Dakota State Geological and Natural History Survey. The publication covers the geological and physiographic features of the state, the climate, the distribution of plant and animal life, and the history of the settlement and present distribution of the population. Some 40 pages of the report are devoted to a discussion of the bio-geography.

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SOME MOUNTAIN PLANT COMMUNITIES OF SANDY SOIL

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I. PHYSIOGRAPHY AND CLIMATE

The plant communities here considered occur in a limited area of sandy soil near Georgetown in north-central Colorado, at an altitude of 8500 feet. The city of Georgetown is located on Clear Creek in a deep valley about a half mile wide. The canyon walls rise quite abruptly 1000 to 3000 feet above the floor of the valley. Various rock exposures occur: granites, gneisses, schists, and some porphyry. Weathering of these rocks leads to various degrees of disintegration and decomposition. Much of the material is of a gravelly nature, having pieces of different sizes intermixed. Again there may be a coarse sand or a sand and gravel mixture. Such soil is common everywhere in the Rocky Mountains and is known as "disintegrated granite." Below Georgetown, however, there is an area in which the lower slopes of the canyon walls are made up of pure sand of rather fine texture and with very little coarse material intermixed. A sample of the sand was examined by Prof. R. D. George, of the Geology Department of the University of Colorado, who states that some of the sand, at least, is probably derived from mine workings or stamp mills. Torrential rains, which sometimes occur, serve to carry down a very large amount of loose material both of natural and artificial origin. There is a likelihood also that some of this sand is of eolian origin, being carried from the valley floor by high winds of winter.

The present paper records a study of the vegetation of this sandy area (see map, fig. 1) which extends a mile along the west boundary of the valley beginning about a half mile north of the

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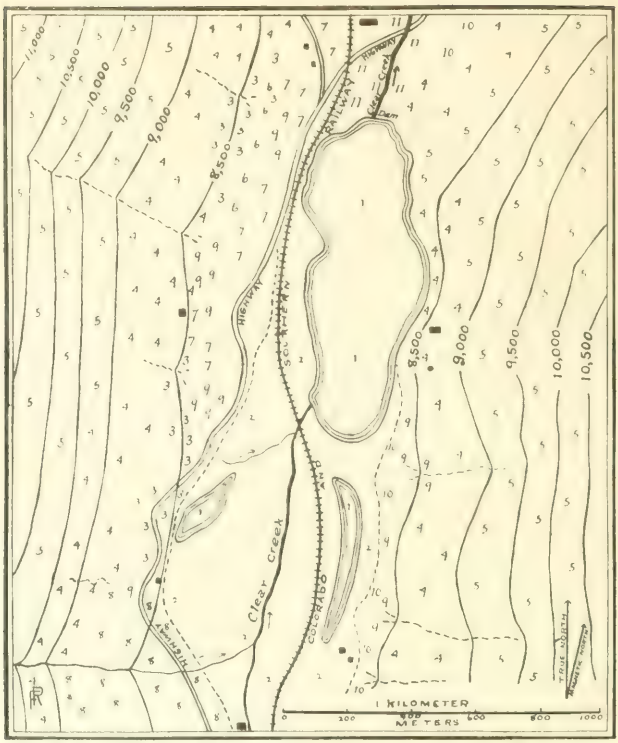

Fig. 1. Map of Clear Creek valley and canyon just north of Georgetown, Colorado. Enlarged with revisions from the topographic map of the Georgetown quadrangle, U. S. Geological Survey; contour interval 500 feet; buildings indicated by black rectangles. The area of the present study is chiefly close to and just west of the automobile highway. The ponds shown on the map are artificial and subject to frequent changes in outline. Arabic figures on the map have the following significance: 1 = standing water; 2 = sand without vegetation, frequently overflowed; 3 = loose sand with shrubs; 4 = sand and rocks with various shrubs and herbs such as are present in inceptive mixed grassland; 5 = same as preceding but with a number of trees; 6 = loose sand with wheat grass; 7 = early stage of Bouteloua association but with many shrubs of Chrysothamnus; 8 = Bouteloua and other short grasses; 9 = inceptive mixed grassland; 10 = derivitive mixed grassland; 11 = streambank fringe forest of alders, willows and cottonwoods.

railway station at Georgetown. In the area of study the canyon side shows alternating gullies and ridges, the gullies having the looser and more sandy soil. Ridges are often of solid rock or rock fragments with only a thin coating of sand or gravelly material. Storm waters bring down large amounts of sand, forming in places wide fans. At a point a few hundred feet away from one of these sand fans the same storm may make a temporary stream that carries gravel and rock fragments. Succeeding storms do not always carry the same kind of material to the same place, as storm waters are constantly making new channels down the canyon walls. Thus a sand fan may come to cover up a rock-wash fan or the opposite condition may occur. Because of the steep slope there is little opportunity for accumulation of humus.

Georgetown, although at an altitude of 8500 feet is in the Foothilll Zone (3) or Submontane Zone (7), as is shown by the presence of plants that do not extend into the montane area: *Eriocoma, Bouteloua gracilis, Opuntia, Pediocactus, Anogra albicaulis, Artemisia brittonii*. The climate is cool, however, with a mean July temperature of about 62° F. and a mean annual temperature of 42°. The coolness of summer may be best appreciated from the fact that only the most hardy garden vegetables can be grown, such as potatoes, beets, lettuce, radishes, and peas. It is too cold for tomatoes, beans or maize, or for apples, plums, and cherries.

The annual rainfall is about 17 inches. April and May are generally wet, June and July quite dry. There is considerable wind, especially in winter and spring. Snow drifts to a considerable extent and much of the ground is exposed a large part of the winter.

II. FLORA

From the preceding sketch of physiography and climate it is apparent that the flora of our sandy area must be meager, and of xerophytic type. The most striking feature of the vegetation is a community of xerophytic shrubs. About 12 species are present all told. In referring to these and to other plants the nomenclature of Rydberg (7) will be followed.

There are three common species in loose sand: *Symphoricarpos vaccinoides*, *Rhus trilobata*, and *Ribes inebrians*. Another, perhaps best called an undershrub, is a species of rabbit-brush, *Chrysothamnus linifolius*.

Aside from grasses and sedges and a single species of rush the herbaceous plants of sandy soil are all dicotyledons so far as recorded. An annotated list including both shrubs and herbs is given at the end of the paper.

In the following account the vegetation is described under four heads according to substrata: (1) Pure sand; (2) Sand-gravel slopes; (3) Rock wash; (4) Rock ridges. Chief attention will be given to plant associations on pure sand.

1. Plant communities on sand

In areas of pure sand without rocks and with very little humus there exist three distinct associations: (a) Shrub association, (b) Wheat-grass association, (c) Short-grass association. Besides these three definite communities various intermediate stages are represented. The first two communities named are highly primitive growths in soft, loose sand. Steepness of slope is an important factor in determining their occurrence. The scrub develops oftener on steep slopes and the wheat grass in more level places. Scrub does, however, appear in some situations where the ground is almost level. Short grass, even more than wheat grass, needs level ground and it requires a soil that is somewhat compact.

a. The *shrub association* (or scrub) in loose sand is composed of large circular growths of the various species. Most abundant is *Symphoricarpos vaccinoides*. *Chrysothamnus linifolius* is also common. *Rhus trilobata* and *Ribes inebrians* are of rather more local occurrence. Three other shrubs occur chiefly where there are rock fragments yet at times they too are found in pure sand. These are *Sericotheca dumosa*, *Cercocarpus montanus*, and *Orcobatus deliciosus*. Among rocks, *Sabina scopulorum* and *Juniperus sibirica* may be found locally in small numbers. In narrow gullies there are the less xerophytic *Prunus melanocarpa*, *Grossu-*

lavia inermis, *Sambucus microbotrys*, *Acer glabrum*, *Amelanchier polycarpa*, *Rosa bourgeauiana*.

Symphoricarpos vaccinoides (fig. 2) may be taken as the most characteristic of the shrubs. It is not confined to the sand but occurs sparingly and as small individuals up and down the canyon, growing in loose disintegrated granite. In sand it is much more luxuriant, forming large clumps commonly 1 to 3 meters across. If two or more of these clumps fuse a single elliptical or otherwise elongated growth results, sometimes 5 or 6 meters long. The plant is able to exist in highly unstable soil. If covered, not too

Fig. 2. *Symphoricarpos vaccinoides* growing in loose sand north of Georgetown, Colorado, in Clear Creek Canyon. The absence of other vegetation is apparent.

rapidly, it grows up through the sand. It also holds its place when the sand around it has been blown or washed away. In this manner mounds may develop 1 or 2 meters high which persist for a long time. The stems of this species are weak and soon bend over, making the plant well suited to sandy soil. The leaves, as in the case of many members of the genus, are subject to great variation in form. Blooming takes place the first or second week of July.

Rhus trilobata, the well-known "skunk bush" of the mountain-front area reaches here its upper altitudinal limit. In appear-

ance, except on close view, the clumps are exactly like those of the *Symphoricarpos*. The plant blossoms in mid July.

Ribes inebrians, a common shrub of the foothills and montane zone, is less frequently found in pure sand than the two already mentioned but it does, at times, form similar appearing growths. This "red currant" blossoms early and the berries are ripe in midsummer.

Chrysothamnus linifolius forms characteristic symmetrical clumps of small size (fig. 3). This "rabbit brush" grows some-

Fig. 3. Scattered undershrubs of *Chrysothamnus linifolius* in sandy soil; Clear Creek Canyon, near Georgetown, Colorado. Wheat grass is invading the spaces between the undershrubs. A mixed shrub growth which will be succeeded eventually by forest may be noted on the steep slope in the background.

times by itself in loose sand, sometimes with grasses in more stable soil. The plants die back part way in the winter. The species blossoms very late in the season, generally in September.

Only a few of the shrubs of the community have conspicuous flowers. *Oreobatus*, the thimble berry, has blossoms in June resembling large white roses. *Sericotheca* with spiraea-like inflorescences in late July is of striking appearance. The *Chrysothamnus* blossoms quite freely giving in autumn a greenish-yellow color to areas where it is abundant.

The herbaceous plants of the shrub association are not numerous and no one of them is especially common or characteristic. *Agropyron smithii* is somewhat abundant; some of the other species are *Tithymalus robustus*, *Lepidium diversiflorum*, *Peritoma serrulatum*, *Eriocoma hymenioides*, *Sophia incisa*. In many parts of the shrub association there are no herbs at all in the spaces between the shrubs.

Probably the high temperature at the soil surface greatly limits the possibilities of establishment of shallow-rooted forms. On September 1, 1919 a thermometer pressed into the sand horizontally just below the surface showed a temperature of 40° C. At a depth of 2 dm. the temperature was 24° C. These readings were taken at 10:00 a.m. with the sun shining directly on the place where the observations were made.

b. Wheat-grass association. This association of *Agropyron smithii* is well known on the plains (2, 9), especially in Wyoming and Montana where it covers large areas. In Colorado it is represented chiefly by a strip running north and south along the mountain front and by isolated patches on the plains and in valleys of the lower foothills. Commonly it serves as an indicator of excellent soil for agriculture. In our present area of study the wheat grass grows chiefly in rather loose sand, becoming replaced by short grass as the soil gains in compactness. It does not develop here a close stand, there being always a large amount of bare ground. Wheat grass is a good soil binder behaving much as beach grass on sand dunes of ocean shores. To one who knows only the typical wheat-grass growth at the mountain front this activity as a sand binder seems quite a new rôle. The writer is familiar, however, with a similar behavior of the species in sandy soil of the plains at Globeville, near Denver, and at White Rocks a few miles east of Boulder.

Very few subordinate species are present with the wheat grass. Most frequent are *Tithymalus robustus*, *Anogra albicaulis*, *Oreocarya virgata*, and *Chrysopsis viscida*. Often a square meter quadrat has no plants other than *Agropyron*. If the soil has an admixture of disintegrated granite there may be some *Stipa* and perhaps various flowering herbs in small numbers, as *Gaura coc-*

parryi, *Artemisia frigida*, *Potentilla concinna*, *P. hippiana*, and *Achillea lanulosa*.

c. Short-grass Association. As frequently described (1, 2, 8, 9) the short grass of the plains is a well-marked association in which the chief species are buffalo grass (*Bulbilis dactyloides*) and grama grass (*Boutelova gracilis*). The former species is more abundant in fine-grained, the latter on slightly coarser soils. As a rule the two occur as separate consociations. In our present area of study the *Boutelova* consociation is established in many places on level or slightly sloping soil. No *Bulbilis* seems to be present; perhaps the climate is too severe. But there are other short grasses of like ecological import which grow in patches much after the fashion of *Boutelova* and *Bulbilis*. These are *Muhlenbergia richardsonis*, *Muhlenbergia cuspidata*, and *Distichlis spicata*. They form rather denser growths, where they occur, than the grama grass.

Short grasses replace *Agropyron* in typical succession. They become established most often as small clumps on patches of ground bounded by shallow rain-cut channels and hence not subject to overwash by sand.

Within the clumps of short grass there are very few subordinate plants, but a meter quadrat may contain relict individuals of *Chrysothamnus* or *Agropyron*, not usually interspersed with the short grass but forming patches alternating with it. A number of meter quadrats have been examined by the writer and the area covered by each species estimated as in previous studies (4). Three of these records may be given as indicating common conditions. The large percentage of bare ground is, of course, to be expected in such sterile soil.

Quadrat 3; short grass

Bare ground	65
Boutelova gracilis	18
Chrysothamnus linifolius	10
Artemisia frigida	3
Agropyron smithii	2
Antennaria arida	1
Tithymalus robustus	1
	100

Quadrat 4; short grass

Bare ground	75
Bouteloua gracilis	20
Chrysothamnus linifolius	4
Mertensia lanceolata	1
	100

Quadrat 6; short grass

Bare ground	85
Muhlenbergia richardsonis	15
	100

2. Plants of sand-gravel slopes

In the steeper parts of the canyon walls having more than 30° slope sand does not accumulate but is washed down farther to the valley floor. There are, however, many slopes of mixed sand and rock fragments. Here the shrub association is well developed although somewhat differently from the way it is on sand. The commonest shrub is not *Symphoricarpos* but *Ribes inebrians* and there are not the large symmetrical clumps of shrubs but smaller and more straggling specimens. The minor species are much the same as seen in pure sand but more abundant. *Artemisia frigida*, as would be expected, is quite common. Grasses are largely absent. A few small trees develop on these slopes, but only where the sand covering is thin and solid rock comes close to the surface. The trees are *Pinus scopulorum*, *Apinus flexilis*, and *Pseudotsuga mucronata*.

3. Plants of rock wash

At a number of points near the base of the canyon walls intermittent or temporary streams have carried out coarse materials upon the valley floor as "rock-wash" fans. The vegetation of these fans depends much upon the coarseness or fineness of the material of which they are composed. In well disintegrated granite one of the rather early communities to develop is a *Carex* grassland, chiefly a thin sod of *Carex stenophylla*. This well-known community of foothill and montane parks (5) is represented especially on the fans derived from Silver Creek (see fig.

1). If the soil is coarse or has many rocks a mixed inceptive grassland (6) develops. Here a considerable number of herbaceous plants appear, the commonest pioneer being *Artemisia frigida*. Other species of frequent occurrence are *Koeleria gracilis*, *Poa crocata*, *Agropyron richardsonis*, *Festuca saximontana*, *Artemisia brittonii*, *Orocarya virgata*, *Achillea lanulosa*, *Gaillardia aristata*, *Opuntia polyacantha*, and the shrub *Ribes inebrians*. The following quadrat record was made on a gravelly slope, part of a rock-wash fan. The figures indicate the percentage of ground covered.

Quadrat 2

Bare ground and rocks	85
Artemisia frigida	7
Artemisia brittonii	3
Bouteloua gracilis	2
Pentstemon unilateralis	1
Potentilla hippiana	1
Machaeranthera viscosa	1
	100

The inceptive grassland here noted is destined to become what the writer has called (6) a derivative grassland, in which there is a closer stand of vegetation with a larger proportion of grasses and fewer species of dicotyledons. At a still later period, if undisturbed, this should gradually develop into short grass, probably the *Bouteloua* consociation. The production of short grass is a slow process which depends upon accumulation of humus and further disintegration of soil particles.

j. Plants of rock ridges

So far as rock ridges have no sand at all they do not afford material for description in the present paper. Practically all ridges of exposed rock down toward the valley floor have some sandy material. On these ridges shrubs are abundant, especially *Ribes inebrians*, *Sericotheca*, and *Cercocarpus*. This shrub community is represented on both sides of the valley, and is, indeed, common on hillsides of the region. Herbaceous plants are such as occur on rock-wash fans and the coarser parts of sand-gravel slopes.

III. GENERAL DISCUSSION

All of the plants collected or recorded in the present study are well-known members of the Colorado flora; most of them occur elsewhere in the neighborhood of Georgetown and are not entirely confined to sandy soil. Some, however, reach in this sandy area a higher altitude than is usual for the species in this part of Colorado. Examples are: *Eriocoma*, *Bouteloua*, *Distichlis*, *Peritoma*, *Rhus trilobata*, *Opuntia*, *Pediocactus*, *Anogra albicaulis*, *Artemisia brittonii*. No doubt, the character of the soil rather than any local climatic condition is the determining factor. Three of the plants just named, viz.: *Eriocoma*, *Peritoma*, and *Anogra albicaulis* may be characterized as "sand dwellers" since they seldom occur abundantly in other soils at any altitude.

In our area of study, mixtures of various plant communities occur in every possible combination because of diversity of soils. For example, a former rock-wash fan has recently, i.e., within a few years, been covered by a layer of sand, now about 4 dm. thick. The sand has been deposited by succeeding storms probably a few centimeters at a time. Some of the former plants remain, chiefly *Artemisia frigida*, but there is an almost equal amount of *Chrysothamnus* with some *Bouteloua*. These are plants that belong, in our area, especially to sand. The *Artemisia* is, then, a remnant of a totally different ecological community. *Chrysothamnus* and *Bouteloua* belong properly to the developing arenicolous flora. Reverse conditions frequently occur. A short grass growth may be covered completely with rock wash. Here a mixed inceptive grassland will develop, dominated at first by *Artemisia frigida*. The shrub growth all along the lower part of the canyon walls is in unusual community for the mountains. The same association, it is true, may be recognized on isolated sunny slopes here and there throughout the region. Scrub also, as is well known (9, 10), is an important feature of the vegetation along parts of the eastern mountain front; but well-developed and clearly-marked scrub belongs rather to the Great Basin and the Pacific States. One naturally compares the scrub at Georgetown with the chaparral of California. Like the chap-

arral it is an ecological community intermediate between forest and grassland. It is less stable and permanent than either of these others. It readily gives way to one or the other with slight differences in angle of slope or depth of soil. In this part of Colorado gentle slope and fine-grained soil favor grassland development; steep slope and coarse soil favor coniferous forest. A belt of shrubs will continue to exist along the base of the canyon wall because more sandy material is continually being brought down from above and because this is again disturbed by rain and wind.

IV. ANNOTATED LIST OF SPECIES IN SANDY SOIL[1]

Juniperaceae, cedar family

Juniperus sibirica; only where sandy covering is thin and solid rock comes close to the surface.

Sabina scopulorum; under same conditions as juniper but quite infrequent.

Poaceae, grass family

Agropyron richardsonii; in coar e sand.

**Agropyron smithii;* often in the loosest, most sterile sand, a good sand binder.

**Bouteloua gracilis;* the typical short grass of the present study dominating the "Bouteloua consociation."

Bromus porteri; in sand with some humus.

**Distichlis spicata;* dense mats in pure sand.

Eriocoma hymenioides; a typical sand species seldom found at such high altitude in Colorado.

Koeleria gracilis; this widely distributed grass occurs here in coarse sand or in disintegrated granite.

**Muhlenbergia cuspidata;* a short grass which develops on sand having a moderate amount of humus.

**Muhlenbergia richardsonii;* a short grass which forms dense tufts in compact sand.

Stipa nelsonii; in coarse sand or in sand and gravel.

Cyperaceae, sedge family

**Carex stenophylla;* in coarse sand and disintegrated granite, often forming thin sod over considerable areas.

Juncaceae, rush family

Juncus ater; only in moist areas of sandy soil.

[1] Stray plants, evidently not regular members of the sand communities, are omitted from the list. The more important species are marked with an asterisk.

Ranunculaceae, crowfoot family

Pulsatilla ludoviciana; in sandy soil with some humus, or on disintegrated granites. Only occasional.

Fumariaceae, fumitory family

Capnoides aureum; along roads and trails in disintegrated granite.

Brassicaceae, mustard family

Cheirinia wheeleri; in coarse sand and disintegrated granite.
**Lepidium densiflorum;* chiefly in fine-grained sand.
Sophia incisa; along roadsides, a plant of "weedy" tendencies.

Cappariaceae, caper family

**Peritoma serrulatum;* this well known "bee plant" usually in fine-grained sand.

Grossulariaceae, gooseberry family

Grossularia inermis; in moister areas along beds of intermittent streams.
**Ribes inebrians;* common shrub in sand or disintegrated granite among rocks.

Rosaceae, rose family

**Cercocarpus montanus;* found only as scattered individuals, never forming pure stand as at the mountain front in northern Colorado.
Dasiphora fruticosa; only where there is some accumulation of humus.
**Oreobatus deliciosus;* chiefly among rocks and in disintegrated granite without much sand.
**Potentilla concinna;* belonging to highly primitive growths in coarse sand.
**Potentilla hippiana;* represented in almost all soils of the area.
Prunus melanocarpa; in moister parts of draws, especially where there is some humus.
Rosa bourgeauiana; occasional in moister areas with some humus.
**Sericotheca dumosa;* chiefly among rocks and in disintegrated granite without much sand.

Fabaceae, pulse family

Lupinus argenteus; on sandy rock-wash fans.

Geraniaceae, geranium family

Geranium parryi; sparingly present on most soils.

Euphorbiaceae, spurge family

Chamaecyce serpyllifolia; only on sand.
**Tithymalus robustus;* typically on sand.

Anacardiaceae, cashew family

**Rhus trilobata;* the well-known "skunk bush" of the mountain front found here on loose sand as well as on stable soils.

Aceraceae, maple family

Acer glabrum; this shrub is occasional along draws.

Cactaceae, cactus family

Opuntia polyacantha; in coarse sand or gravel, not frequent.
Pediocactus simpsoni; in coarse sand, only a few specimens seen.

Onagraceae, evening primrose family

**Anogra albicaulis;* typical sand dweller.
Anogra coronopifolia; chiefly in coarse sand or sand and gravel.

Polemoniacea, phlox family

Gilia calcarea; in sand that is somewhat compacted or in disintegrated granite, never in loose sand.
Gilia spicata; a plant often found in primitive xerarch communities occurring here in coarse sand.
Polemonium sp.

Boraginaceae, borage family

Mertensia lanceolata; coarse sand or disintegrated granite.
**Oreocarya virgata;* a common plant of primitive xerarch growths, rather common here in all soils.

Verbenaceae, verbena family

Verbena bracteosa; along roads and trails in almost any kind of soil, never abundant.

Scrophulariaceae, figwort family

Penstemon humilis; in compact sand or disintegrated granite.
**Penstemon unilateralis;* shows a strong tendency to be confined to pure sand.

Caprifoliaceae, honeysuckle family

Sambucus microbotrys; in moister parts, especially where there is some humus.
**Symphoricarpos vaccinoides;* commonest shrub of loose sand but also present to some extent in disintegrated granite.

Carduaceae, thistle family

**Achillea lanulosa;* scattered throughout except in pure sand.
Antennaria arida; a common plant of primitive growths, present here in the coarser soils.
**Artemisia brittonii;* a plant common in primitive communities in the lower foothills, present here in all coarser soils.
**Artemisia frigida;* widely distributed in the Rocky Mountains in primitive communities of the xerarch succession, present here in all soils except loose sand but more common in disintegrated granite.

Aster porteri subfoliosus, seen only in rather loose soil.
**Chrysopsis viscida;* abundant in all soils.
**Chrysothamnus linifolius;* frequent in pure sand which is but slightly compacted.
Colcosanthus umbellatus; infrequent in rather fine grained sand among rocks.
Gaillardia aristata; in coarse sand and disintegrated granite.
Machaeranthera aspera; infrequent, in all soils.
Senecio fendleri; a plant common in primitive growths of foothill and montane zones, present here in coarse soil.
Senecio pudicus; rare, in compact sandy soil.
Senecio spartioides; in the various soils, especially where there is some humus.
Solidago glaberrima; in moister situations, sandy soil with some humus.

V. SUMMARY

The article presents an account of the vegetation of a sandy area in Clear Creek Canyon near Georgetown, Colorado, in the Rocky Mountains, at an altitude of 8500 feet. Physiography and climate are first briefly considered and then the plant communities of each habitat are described. Chief attention is paid to a shrub association, developing typically in loose sand, the most characteristic species of which are *Symphoricarpos vaccinoides*, *Rhus trilobata*, *Ribes inebrians*, and *Chrysothamnus linifolius*. Other plant communities represented on pure sand are the wheat-grass association and the short-grass association. Wheat grass, *Agropyron smithii*, is an effective sand binder. Brief mention is made of the coarser soils having only a moderate amount of sand and the associations developing thereon. There is some discussion of the genetic relationships of the different communities. It is pointed out that the shrub communities are to be considered as intermediate ecologically between grassland and coniferous forest, that well-compacted soil tends to forest on steeper slopes and to grassland on level ground. A map of the area studied and two photographs are used for illustration. An annotated list is given of 64 species of seed plants occurring in sandy soil with a special designation of those which are most important.

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NUTRIENT REQUIREMENT OF THE POTATO PLANT

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The importance attached by investigators to the nutrient requirements of plants is shown by the increased amount of work being done with sand and water cultures. Little if any work of this nature has been done with the potato plant. The behavior and growing habits of the potato make it less susceptible of this kind of study than such plants as wheat and rice. Special methods must therefore be devised before anything like comparable results can be obtained for this plant. Because of the economic importance of the potato, preliminary experiments have been started for the purpose of ascertaining methods of attacking the problem of its nutrient requirement.

In problems of this nature it is essential to obtain uniform plants at the beginning of the experiment. Differences in growth may then be attributed to differences in treatment. Individual hereditary characteristics of course are always present, but of necessity must be neglected. It is assumed that if plants or seedlings are exactly alike as to their external appearances, their internal characteristics will differ less than those that are unlike externally. In water and sand culture work with wheat, uniform seedlings, sprouted from a pure strain of seed can be selected with comparative ease. With the potato the problem of selecting uniform plants is exceedingly difficult. This problem is further complicated by the presence of the tuber on which the plant grows.

An attempt was made to secure uniform potato plants by growing cuttings from the stems of old vines. This method proved unsatisfactory as most of the cuttings produced small tubers rather than roots and leaves. Figure 1 illustrates cuttings from Irish Cobbler stems. The tendency toward tuber

formation was found to be greater in the Cobbler than in the McCormick.

It is not difficult to select fairly uniform sprouts from a large number of tubers and the possibility of using these sprouts when cut from their tubers suggested itself as a means of securing uniform plants. Two sets of sprouts with well developed roots were taken from similar seed pieces and planted in glazed pots containing good garden soil. Each set of three plants was watered by means of three Livingston auto-irrigators.[1] In one set,

Fig. 1. Small tubers growing on cuttings from potato vines.

sprouts were used whose leaf buds had just begun to grow, while in the other, sprouts with four or five leaves each approximating a square centimeter in area were employed.

The sprouts were planted on October 17, 1918, and by the following February the plants had grown to maturity and died.

[1] Livingston, B. E. A method of controlling plant moisture. Plant World **11**: 39–40. 1908.

Hawkins, Lon A., The porous clay cup for the automatic watering of plants. Plant World **13**: 220–227. 1910.

Livingston, B. E., and Lon A. Hawkins, The water relation between plant and soil. Carnegie Inst. Wash. Pub. **204**: 5–48. 1915.

All the plants were very much under size and the new tubers that had formed were small. The difference in growth of tops is clearly seen in figure 2. The set of less developed plants formed seven tubers averaging 4.7 grams each, while the set of the more developed ones formed six tubers averaging 8 grams. The growth of these plants seemed directly related to the developmental stage of the sprouts at the time they were separated from their tubers. Appleman[2] has shown that the vigor and sub-

Fig. 2. Differences in vigor and growth of potato plants when grown from sprouts separated from their tubers at different stages of maturity.

sequent development of a potato sprout is greatly influenced by the size of the seed piece. Sprouts on seed pieces weighing less than 1.5 ounces are usually weak and tend to develop into weak plants. The smaller the seed piece the greater this tendency becomes. The facts found by Appleman indicate the presence in the old seed piece of some growth-promoting substance that is needed by the growing sprout for its normal development.

[2] Appleman, C. O., Physiological basis for the preparation of potatoes for seed. Md. Agric. Exper. Sta. Bull. 212. 1918. Special growth-promoting substances and correlation. Science n.s. **48**: 319-320. 1918.

In plant nutritional studies the more definite the culture medium can be described the greater is the possibility of a true interpretation of results. A nutrient solution is more easily and definitely described than either a soil or sand medium. A solution is therefore more nearly an ideal medium. A sprout from an Irish Cobbler tuber, taken at the stage where its leaves had begun to develop, was placed in a paraffined cork stopper and its roots immersed in a nutrient solution. The plant grew for about two months, but never attained anything like normal size. In the saturated air space between the bottom of the cork stopper and the surface of the solution several tubers developed. Figure 3 illustrates the appearance of this plant shortly before the end of the experiment. The aerial portion of the plant did not differ materially from those planted in the pots of garden soil (fig. 2).

Although the results of these two experiments were far from satisfactory in finding a method for successfully studying the nutrient requirements of the potato it was thought worth while to continue the work still further along this same line.[3] Potato sprouts, after being separated from their tubers, were grown in a series of nutrient solutions. Six three-salt solutions were selected from those being employed by coöperators with the National Research Council in the salt nutrient studies of plants. About 60 McCormick potato tubers of approximately the same size and with their first sprouts of uniform appearance and about 1.5 cm. long were selected from several hundred stored in a vault. These tubers were planted in moist sawdust in the open on May 16, 1919. On June 5, sprouts of approximately 10 cm. in length with well developed roots and with leaves started, were separated from their tubers. The roots were washed in tap water, then soaked in distilled water for about fifteen hours, after which they were weighed and set in the cork stoppers of solution jars. Each culture comprised a single plant, suitably supported in a quart glass jar filled with a nutrient solution. Most of the light was excluded from the roots by wrapping the

[3] Skinner, J. J., Water culture method for experimenting with potatoes. Plant World 11: 249-254. 1908.

jars with opaque paper. The cultures were run in triplicate and the solutions renewed every ten days. The plants were sealed

Fig. 3. A potato plant grown from a sprout in water culture, showing the formation of new tubers.

in the stoppers so as to prevent the entrance of rain for the experiment was carried out in the open because of the extreme heat in the greenhouse at this season of the year.

The solutions employed had an osmotic pressure of one atmosphere and contained the following salts; monobasic potassium phosphate, calcium nitrate and magnesium sulphate. In the triangular arrangement of the twenty-one culture solutions chosen by the Committee on Salt Nutrition of Plants[1] the three at the apices of the outer triangle and the three at the apices of an inner triangle were the ones used in this work. These culture solutions are designated as R1S1, R1S6, R2S2, R2S4, R4S2 and R6S1 of type I and their positions are shown in the diagram of figure 4.

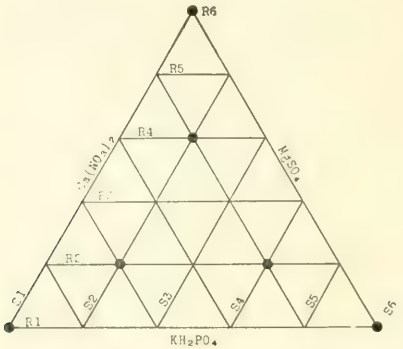

Fig. 4 Position of six selected solutions on triangle of 21 solutions.

The cultures were continued for thirty days after which the green and dry weights were determined. The green weights were also determined at the time the plants were placed in the solutions. At the end of the second and third ten-day periods transpiration measurements were obtained. The results of this experiment are given in tabular form in table 1. Averages of three plants are considered except where otherwise indicated by small superscript figures.

[1] See "Salt requirements of representative agricultural plants." Science n.s. 49: 143. 1919. See also the specially prepared plans obtained from the chairman of Committee on Salt Requirements of Plants, Laboratory of Plant Physiology, The Johns Hopkins University, Baltimore.

The size of the plants was far below normal and their color, in general, was a light green or yellow. At the end of the experiment the roots were much discolored and in several cases had rotted off. It is evident that normal healthy plants can not be grown by this method. There was, however, some growth as is shown by the increase in green weight. Three sprouts similar in size and appearance to those placed in the solutions were dried and weighed at the beginning of the experiment. Their dry weights were 0.56, 0.64 and 0.62 gram, giving an average of 0.61

TABLE 1

SOLUTION NUMBER	PROPORTIONAL PART OF TOTAL OSMOTIC PRESSURE			AVERAGE PERCENTAGE INCREASE IN GREEN WEIGHT	AVERAGE DRY WEIGHT	TRANSPIRATION FOR	
	K	Ca	Mg			Second 10-day period	Third 10-day period
					grams	*grams*	*grams*
R181	1	1	6	37	1.27	41.0	93.9
R186	1	6	1	80*	1.35*	69.0*	163.2*
R282	2	2	4	68	1.29	61.1	147.0
R284	2	4	2	75*	1.45*	62.2*	146.7*
R182	4	2	2	49†	0.90†	57.6†	97.4†
R681	6	1	1	41	0.97	46.3	100.5

* Two plants in average.

† One plant in average.

gram. When the dry weights as given in the table are compared with this average initial dry weight there is further evidence of growth. The plants of the cultures R186 and R284, where the total osmotic pressure is mostly due to calcium nitrate, seem to have grown best as indicated by percentages of increase in green weight and by their greatest total dry weights. These plants also usually transpired more than the others. Three plants grown in distilled water died before the end of the period.

CONCLUSIONS

The growing of cuttings from potato vines was an unsatisfactory method of obtaining uniform potato plants.

Normal potato plants were not produced either in good garden soil or in nutrient solutions from sprouts separated at an early developmental stage from their tubers.

The roots of potato sprouts showed a marked tendency to rot when grown in nutrient solutions.

Best growth was obtained from plants grown in a three-salt solution where most of the osmotic pressure was due to calcium nitrate.

Plants of the Irish Cobbler variety showed a greater tendency to form new tubers than those of the McCormick variety.

ROOT CONTRACTION

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The first reference in the literature to root contraction according to Hugo de Vries[1] is that of Tittmann[2] in Flora for 1819. Under "Wurzelbildung" Tittmann describes contraction of the roots in *Daucus Carota:*

> Der Stengel wird dicker und kürzer, zieht sich gleichsam in die Erde hinein oder wird von derselben angezogen und man findet dann nach einiger Zeit die langen Saamenblätter dicht auf der Erde ausgebreitet. Untersucht man in dieser Periode die Wurzel, so hat sich die Gränze zwischen ihr und dem Stengel, der sich nun auch in der Erde befindet, ganz verloren und ausgeglichen.

De Vries[1] himself worked principally with dicotyledons, experimenting with eighteen species of plants. He studied the effect of exposure to air, to water and to salt solutions on strips, separate pieces of definite tissue, and single cells of roots. He measured changes in length, width, and volume of tissues and cells. He considered roots from plants still bearing succulent cotyledons to those two years of age. He studied young roots and roots two years old. Each experiment is considered in itself and in the light of previous experiments, until at last de Vries concludes that root contraction is not due to intake of water but to changes in turgor, and remarks in addition that the thoughtful reader will ask "durch welche Ursachen die ungleiche Dehnbarkeit der Zellhäute selbst bedingt wird."

[1] Vries, H. de. Ueber die Kontraction der Wurzeln. Landw. Jahrb. **9**: 37. 5 figs. 1880.

[2] Tittmann, D. J. A. Botanisch-karpologische Bemerkungen. Flora **2**: 651. 1 19.

Rimbach discusses root contraction as it occurs in *Colchicum autumnale*,[3] *Arum maculatum*,[4] and *Allium ursinum*.[5] He found that in the case of naturally deep-set bulbs of *Allium ursinum* a depth of 10 to 15 cm. was attained after several years by the contraction of the roots. In the explanation as to how contraction in roots comes about he states that, while the root tip holds firmly to the earth particles, the endodermal cells contract longitudinally as a result of a tendency to lengthen radially and tangentially, which results in the contraction of the root. The bulb yields to this pull, which results in the contraction of the roots, and is gradually placed more deeply in the ground with each new set of roots. Even the upward development of the shoot, where each successive scale is formed at a slightly higher level, does not counteract entirely this downward movement of the bulb. Therefore the bulb is continually placed more deeply in the soil.

In *Arum maculatum*, Rimbach[4] explains, the active portion of the root consists of the cells directly below the epidermis and the "hypodermal layers." These cells shorten in their length as much as one half and their radial walls lengthen somewhat. The vascular bundles and their accompanying cells are not active. However, the latter respond sufficiently to the vertical pressure caused by the shortening of the parenchymatous cells just outside them to show regular wrinklings along their walls, and the tracheal tubes themselves shorten between the rings.

Rimbach's careful observations and well chosen biological experiments are not supported by his theoretical conclusions. Because he has accurately noted that endodermal cells lengthen radially, he proceeds to state that they shorten longitudinally and therefore the whole root contracts with the result that the bulb is set more deeply into the ground. All other tissues are passive, yet they must be shortened in the shortening of the whole root. Without sufficient morphological proof Rimbach claims that the

[3] Rimbach, A. Biologische Beobachtungen an *Colchicum autumnale*. Ber. deutsc. bot. Ges. **15**: 298. Pl. 12. 1897.

[4] Rimbach, A. Ueber die Lebensverhältnisse des *Arum maculatum*. Ibid. **15**: 178. Pl. 5. 1897.

[5] Rimbach, A. Lebensverhältnisse des *Allium ursinum*. Ibid. **15**: 248. Pl. 8. 1897.

outer or cork cells are crushed and killed, and the vascular cells are thickened. The outer cells are crushed doubtless, but do they die first, are they killed by the crushing? His further conclusion that the vascular cells thicken may be true, but where is his proof? To return to the active or endodermal cells—how can we accept the statement that because a cell lengthens in one direction therefore it must necessarily shorten in another? Volume being constant and cell wall composition and tension being similar at every point this would be true. But Rimbach did not investigate these points.

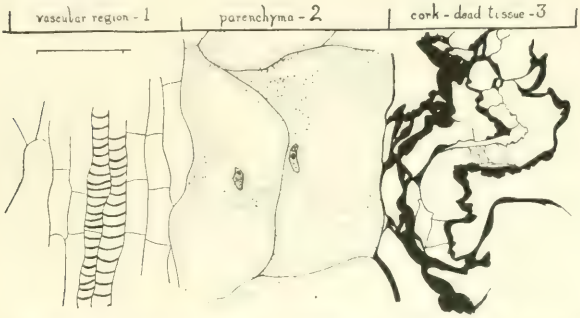

Fig. 1. Section of root of *Cooperia Drummondii*. The scale is equal to 0.1 mm.

Rimbach states that ripples may be seen on the root surface even to the root-ends with the naked eye. Microscopic slides have proven to the writer that the process of root contraction is well under way in a five-day-old seedling of *Cooperia Drummondii* at points not visible to the naked eye. The ripples in individual cells in the case of *C. Drummondii* are not confined to radially placed cell walls as Rimbach finds them to be in the species which he investigated. On the contrary they may be found on walls running in any direction. In some stages they are so fine as to be distinguishable only with the oil immersion objective, but always numerous cells with rippled walls may with care be detected in the parenchyma cells of the root with a combination of 10 ocular and 8 objective.

The warped and altogether disorganized condition of the epidermis and "hypodermal" layers in the contracted roots of *Cooperia Drummondii* may be comprehended by study of the tissues represented by the blackened areas in the figure, section 1.

It seems safe to accept these facts: (1) roots do shorten; (2) the parenchymatous tissues of the root are the seat of activity; (3) the cork and the vascular trace are passive; (4) the cork is ultimately crushed; (5) there is a region where one can see wrinklings and measure shortening, a second region where no wrinklings are visible yet one can measure shortening, and an unchanged region (Rimbach); (6) in dicotyledons the trace becomes visibly curved inward and outward in a wavy fashion, while in monocotyledons the vascular bundles remain practically straight (de Vries).

What remains to be determined in regard to root contraction constitutes a problem of botanical research as yet unsolved. We may hope that some worker with an interest in morphology as well as physiology may master this problem by a study of serial sections of young roots and a consideration of the physical relations of turgor and biochemical alterations in the protoplast and cell membrane.

BOOKS AND CURRENT LITERATURE

Fossil Plants.—The fourth and concluding volume of the Cambridge text on fossil plants, is devoted to a consideration of the Ginkgoales, Coniferales and Gnetales.[1] The final proofs were passed in the Spring of 1918 but the printing was held up because of war conditions so that a number of recent contributions could not be considered. The method of treatment in the present volume is consistent with that of the preceding volumes and the same lack of balanced treatment is shown in the present work. To cite but a single instance of this, six lines are devoted to the remains of *Ginkgo* from North America although *Ginkgo* is exceedingly well represented in the Mesozoic and early Eocene on this continent.

As regards the subject matter, a chapter is devoted to the Ginkgoales, recent and fossil. The second chapter considers *Ginkgoidium*, *Czekanowskia*, *Feildenia*, *Phoenicopsis* and *Desmophyllum*,—genera that are believed to belong to the Ginkgoales. The third chapter includes supposed Ginkgoalean genera of still more doubtful allegiance. The nine following chapters are devoted to the Coniferales. There is a rather full and excellent account of recent Conifers. These are grouped in the following nine families: Araucarineae, Cupressineae, Callitrineae, Sequoiineae, Sciadopitineae, Abietineae, Podocarpineae, Phyllocladineae and Taxineae. They are considered as probably monophyletic, the Araucarineae being regarded as the most ancient and the Abietineae as the most modern. There are some illuminating discussions of vascular anatomy, and the view is expressed that the cone scales in the Araucarineae are morphologically simple ovuliferous leaves, the double cone scales of the Abietineae being derivatives of a simple form of sporophyll. *Mesembrioxylon* is proposed for the fossil woods formerly referred to *Podocarpoxylon* and *Phyllocladoxylon*. The final chapter is devoted to the Gnetales and is without noteworthy features.

Opinion will differ as to the necessity or desirability for some of the new generic terms that are proposed, e.g., *Ginkgoites* for *Ginkgo* leaves, on the ground that even in the Tertiary forms the confirmatory

[1] Seward, A. C. Fossil Plants. Vol. IV. Cambridge University Press (New York, G. P. Putnam's Sons) 1919.

evidence of flowers and fruits is lacking: *Cupressinocladus* for vegetative shoots of conifers of a cupressoid habit: and *Pityites* for abietineous fossils of uncertain generic relationship. There is but slight profit in compounding confusion and although a conservative attitude is warranted in dealing with the vegetative remains of conifers there is but slight evidence in the more recent history of the study of fossil conifers to show that stem anatomy or strobilar morphology furnish any easier read or more definite criteria than vegetative habit, and from the nature of the remains we cannot hope to have all of the criteria in individual cases. Even the older students in dealing with foliar impressions were not guilty of more pretentious absurdities than have been put forward under the banner of anatomy during the past decade.

The present volume contains 190 illustrations, which on the whole appear rather uniformly better than those of volume III although it is difficult for the reviewer to understand why paper and presswork were wasted on such illustrations as that forming the frontispiece of the present volume. The bibliography, which has a certain air of completeness, really contains not more than about twenty percent of the literature, but perhaps this should not be criticised since it avowedly contains only "papers and works referred to in the text."

On the whole it seems to the reviewer that Professor Seward has performed a difficult task about as well as could be expected, and despite their obvious shortcomings, which have been freely criticised, these four volumes are a mine of information for the student interested in the floras of the past.—Edward W. Berry.

Ecology of Roots.—The importance of the distribution of root systems has long been appreciated, and ecologists have realized that the subterranean organs of plants are quite as important as the aerial parts in determining the relation between the plant and its environment and between associated plants. The study of root systems has been delayed, however, by reason of the active exercise which must precede even the simplest observations of their extent and character. A few important pieces of work have been done in recent years, to which Weaver has just added a notable contribution.[1] An investigation extending over several years has resulted in the examination of 1150 individual root systems in eight plant communities in Nebraska, Washington, and Colorado. The distinctive root habits of 140 species

[1] Weaver, John E. The Ecological Relations of Roots. Carnegie Inst. Wash. Pubn. 286. Pp. 128, figs. 58, pls. 30. 1919.

of trees, shrubs, grasses and other herbaceous plants were determined. Rainfall, soil moisture, evaporation, and wind were measured in each of the communities. It was found in several cases that the type of root system in a given species is determined by the character of the environmental conditions and the nature of the soil, although there are other cases in which the type is specific and relatively constant. A great deal of light has been thrown by Weaver's work on the layering of root systems and the "competition" between roots of different plants in the same soil level.

In the prairies of eastern Nebraska more than half the species examined penetrate beyond 5 feet (including *Panicum virgatum*, *Andropogon furcatus*, *A. scoparius*, and *A. nutans*) and many to 7 and 9 feet. Although there are 20 inches of rain in the growing season in this region it was found that there are times in that season when there is no available soil moisture down to a depth of 5 feet. It is in this soil that layering was found most common. In the prairies of southeastern Washington more superficial root systems prevail, in correlation with a lower rainfall and earlier seasonal development. In the so-called chaparral of southeastern Nebraska some very deep-seated roots were found, *Rosa arkansana* reaching 21 feet. On the plains near Colorado Springs the roots of many characteristic species, including the grasses, are found chiefly between 2 and 5 feet, although more than half of the 28 forms examined penetrate beyond 5 feet and down to 10 to 13 feet. The lateral spread of the roots is greater here than in the prairies. In the Rocky Mountains, near Colorado Springs, work was carried on in the open vegetation of the gravel slides, the more nearly closed half gravel slides, and the forest. The first of these habitats is characterized by shallow soil and superficial root systems, with no competition; the second by both shallow and deep systems down to 4 feet, with all the soil exploited by roots at 3 feet. In the forest the roots of trees, shrubs, and herbs are found mainly in the first 18 inches. Determinations from June to August showed a decrease of soil moisture with increasing depth, down to 3 feet.

Many characteristic root systems are illustrated, and a series of colored plates is used to map the distribution of the roots of associated species, as seen in a vertical section of the soil. The publication as a whole forms a very substantial contribution to an important and neglected field of work.—Forrest Shreve.

NOTES AND COMMENT

Professor F. O. Bower has contributed to the Macmillan Company's Men of Science series a short life of Joseph Dalton Hooker. The book is of particular interest in its portrayal of the intimate relations between Hooker and Darwin, and is calculated to make us realise that the older taxonomists contributed more to the advancement of general biological principles than we of the present generation are apt to credit them with doing.

The activity of the botanists of Switzerland in investigating the vegetation of their highly diversified country is indicated by the appearance of the seventh contribution published under the auspices of the Phytogeographical Commission of the Swiss Natural History Society. This is a description, by Dr. August Roth, of the vegetation in the vicinity of the Walensee, in the cantons of Glarus and St. Gall. The distributional map which accompanies the paper is one of those splendid pieces of work that it is to be hoped American printers and publishers can one day learn to match.

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THE GEOLOGICAL HISTORY OF THE SWEET GUM AND WITCH HAZEL

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No part of the Temperate Zone can compare with southeastern North America in the brilliancy of autumnal foliar display and a considerable part of this is due to the sweet gum, whose leaves assume a variety of shades ranging from rich yellow through carmine to wine red.

The sweet gum belongs to a family, often called the Witch Hazel family (Hamamelidaceae), whose present geographical distribution is of remarkable interest. The family comprises nineteen genera in all and about fifty living species, and no less than nine of these genera are monotypic, that is to say, they are each represented by but a single existing species.

Monotypic genera are either geologically old or else very modern, that is, their single species may have been recently evolved or it may represent the last remaining descendant of a long and now extinct line, and it is usually possible to get some idea as to which of these categories we are dealing with by a consideration of the present geographical distribution of the different members of a plant family. In the case of this family twelve of the nineteen genera are confined to Asia, one is prevailingly Australian, three are African and three are confined to Asia and southeastern North America.

Both the sweet gum and the witch hazel belong to this last category, their present range being shown approximately on the accompanying sketch map (fig. 1). It is obvious that a distribution such as this indicates that the family to which they belong had an extended geological history and that the particular genera once flourished in regions that connect the present discontinuous occurrences. The only alternative is to suppose that the

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present disconnected areas of distribution represent special creations—which is absurd, or to suppose that the same genus originated independently on different continents, which is almost equally absurd. The details of the geological history of the Witch Hazel family are for the most part unknown because of the imperfection of the geological record.

Fig. 1. Sketch map showing the existing limits of distribution of the sweet gum and witch hazel with the Tertiary occurrences of the sweet gum indicated by solid black circles.

Although the modern sweet gum rivals the red maple or the dogwood in the brilliancy of the autumnal tints of its star-shaped leaves, it was considered practically worthless as a wood until within the past few years, owing chiefly to its tendency to warp and twist. It was formerly left standing in logging operations and when land was cleared for agricultural purposes, the sweet gum was girdled and left to rot. But times and opinions change and the demand for the wood has increased rapidly since about the year 1900.

Not only does the heartwood make a most attractive interior finish, especially for panels, doors and woodwork in its natural color—abroad it is often called satin walnut—but it takes stain so well that it is often made into mahogany, oak and walnut furniture. Sapwood and the common grades go into boxes, cheap furniture, flooring, staves, etc. There is a large export trade in the heartwood, possibly as much as 50% of the supply going to England, France and Germany, where its beauty for interior finishing was recognized earlier than it was in this country.

The sweet gum occasionally grows to a height of 150 feet and a diameter of 5 feet. Such dimensions are, however, unusual and the average diameter of large trees is perhaps 30 to 36 inches, indicating a normal age of from 150 to 350 years, the size being dependent on the habitat. The trees of the rich bottoms of the south Atlantic coastal plain grow much faster than those of the lower Ohio valley. The stem is straight and columnar and until the height growth is attained the high trunk and conical crown make it resemble a conifer. After reaching its height growth it branches freely and the crown becomes rounded and spreading. Its deeply furrowed bark and cork winged twigs are familiar to every explorer of swamps in our southern states.

The earliest popular name, sweet gum, doubtless originated from the local use for chewing of the sweetish gum obtained from the tree. The later name, red gum, refers to the reddish brown color of the heartwood and its use has become increasingly common since the decorative qualities and commercial possibilities of the wood have come to be appreciated. It might be stated parenthetically that the red gum is not related to the black, cotton and tupelo gums so common in similar situations throughout the southeastern United States, which belong to the genus *Nyssa* and are related to the dogwood.

The red gum belongs to the genus *Liquidambar*, a name derived from the latin for amber colored gum in allusion to the balsamic exudation or gum which it yields. The tree is a native from southwestern Connecticut to southeastern Missouri and southward to peninsular Florida and eastern Texas. It reappears in a closely related form known as the variety *mexicana* in the uplands

of central and southern Mexico and the highlands of Guatemala. While its range is extensive and its habitat varied it reaches the largest size and commercial possibilities in the rich bottom lands of mixed hardwoods in the maritime districts or coastal plain of our southern states from the valley of the Great Pedee in South Carolina to the valley of the Trinity River in Texas, and northward along the bottoms of the Mississippi, Arkansas, Tennessee and Ohio. In the more northern part of its range it inhabits swamp borders and low wet swales.

There are at least three additional existing species of *Liquidambar*—one *Liquidambar macrophylla* Oersted, found in the mountains of Central America, while the other two are asiatic. *Liquidambar formosana* Hance is found on the island of Formosa and in southern China, and the other separated from it by the whole breadth of the Asiatic continent, is found in a limited area in the mountains of southwestern Asia Minor. The last was named *Liquidambar orientalis* by Miller and is the source of the liquid storax of commerce.

This disconnected distribution of the existing species of *Liquidambar*, which can be better appreciated by a glance at the accompanying map, figure 1, is a sure indication of an ancient lineage and a former occupation of the intervening areas where it is now extinct. If the sweet gum stood alone in having such a remarkable range its interest would seem much greater, but since the days of Asa Gray's American Association address we have become accustomed to many similar ties across the departed ages that formerly connected and now explain the near kin found in Asia and North America exemplified also by the magnolia, sassafras, coffee-bean and tulip tree.

Turning to the fossil record we find that about twenty extinct species of *Liquidambar* have been described. The oldest of these, *Liquidambar integrifolius*, described by Lesquereux from the Upper Cretaceous Dakota sandstone of Kansas and subsequently identified from Canada, Texas and South America, cannot be looked upon as the Abraham of the race of gums for unfortunately for our story its coriaceous and entire-margined leaves are not those of a *Liquidambar* but probably represent a

species of *Sterculia*—a tropical genus of trees that was very common in Upper Cretaceous times throughout the northern hemisphere. The same comment applies to an early Eocene form described from France by Watelet, a student of the fossil floras of the Paris Basin.

The oldest known authentic form is found in the upper Eocene in Greenland, Alaska and Oregon. This hints at the Arctic region as the original home of the genus—a not improbable hypothesis, although one for which the evidence is not conclusive, since the vast and almost unknown expanse of Asia cannot be left out of the reckoning. What is more remarkable is the fact that these ancestral gums of three or more million years ago and all of their numerous descendants are so like the sweet gums of today. They had the same palmately lobed and variable leaves with finely toothed margins, and this resemblance extends even to the consistency of the leaves. Today in our southern rivers the sweet gum leaves are the first to decay when they fall in the water and similarly in the Pliocene river deposits the gum leaves are rarer and nearer dissolution than the leaves of their associates. Judging by their usually fragmentary condition in the older rocks this characteristic was as true then as now.

Let us emphasize then the first landmark in the history of the sweet gum, namely that the oldest known authentic species occurs in the late Eocene of the far north and on our Pacific coast in Oregon and Alaska.

Following the Eocene is the period of earth history known as the Oligocene, and it is a striking commentary on the imperfection of the geological record that the only known Oligocene species of gum is recorded from Italy. This is not quite as bad as it seems when it is recalled that we know nothing of the Oligocene history of Asia and that in North America the Oligocene was a time of continental mountain basin and plains deposits throughout the west and of tropical marine deposits along the southern coasts, in neither of which are to be found many traces of the terrestrial vegetation of that time.

The Oligocene was followed by Miocene times and these fortunately are not so chary with their evidence. About nine spe-

Fig. 2

(Three-fourths natural size)

1–3. Liquidambar europaeum Alex. Braun. Variously lobed leaves and young fruits from the upper Miocene of Baden.

4–6. Liquidambar pliocaenicum Geyler. Waterworn fruits from the upper Pliocene of Germany.

7 and 8. Liquidambar styraciflua Linne. Leaf and fruit from the Pleistocene of North Carolina.

cies of sweet gum are recorded from Miocene rocks, most of them surprisingly like the modern gum. There are species from Japan on the east and from southwestern asiatic Russia on the west. The European records are innumerable and widely distributed and the American records include Oregon and Colorado. If the reader will turn to the accompanying plate the resemblance of these ancient flowers, fruits and leaves to those of today will be at once apparent. These figures are taken for the most part from the wealth of remains preserved in the tiny Miocene lake of Oeningen on the Swiss border of Baden, and the leaves show the same variation of three, four, five or more lobed forms such as can be matched today in any southern swamp.

The Miocene was followed by the Pliocene and the gums were still cosmopolitan in the northern hemisphere so that it is easy to see why their distribution is what we find it to be at the present time. Pliocene gums have been found at very many localities throughout central and southern Europe as well as on our Atlantic coast. I have reproduced a worn gum ball collected from the Pliocene deposits along the Main River in Germany on the accompanying plate, and the fruits found in the late Pliocene of Holland are indistinguishable from those of the existing species of Asia Minor.

The Pliocene was followed by the Pleistocene or Glacial time and the gums found fossil in this comparatively recent geological period include traces of the existing Formosa and south China species, which then still flourished in Japan, and the abundant leaves and fruits of the existing red gum which have been found in West Virginia, North Carolina and Alabama. A leaf and fruit from the Pleistocene swamp deposits along the Neuse River in North Carolina are shown on the plate.

That the gums which were so abundant throughout Europe in the late Tertiary should have been entirely exterminated by the glacial conditions while they survived in North America and Asia seems strange but is readily understood when it is recalled that high mountains and seas from the Pyrenees to the Caucasus made it impossible for the gums to escape southward to more genial climes and to return to the northward again when the cold

stages were past, as was possible in both Asia and North America. The gum was only one of the many forest trees of the European Tertiary that met this fate. The witch hazel, tulip tree, hickory, walnut, magnolia, and many others shared the same misfortune. By way of contrast with the present distribution of the sweet gum the accompanying map shows the Tertiary occurrences, thus illustrating something of the past history as it has just been related.

The record of the sweet gum ancestry does not go back so far nor is it as detailed as that of many of our forest trees, but it does cover several million years and all of the continents of the northern hemisphere, and it is surely impressive when we recall that while we have collected the gum balls, as the fruits are commonly called, admired the shape of the leaves and their autumnal tints, it remained for the twentieth century to discover the beauty of the wood and utilize it for interior finishing.

The witch hazel is closely related to the sweet gum but is sharply contrasted with it in size, in leaf habit, in flowers and fruits. It is small and elfish of stature, with zig-zag branches, coarse prominently veined simple leaves, bilocular woody capsules with large bony seeds, and fringe-like bright yellow flowers. Blooming in the winter it is a favorite topic for discussion whether the witch hazel is the last flower of fall of the first flower of spring. The persistence of the fruit of the previous season until the flowering time comes around again has suggested the scientific name of the genus Hamamelis, derived from the Greek words ἅμα, with, and μῆλον, fruit.

The witch hazel is an altogether different plant from the old saxon witch or wych hazel, a name applied to the common European hazel nut which was Thor's tree and a magic tree as well. Opinions differ as to the origin to the fact that the twigs were long reputed to have magic properties as divining rods—not, however, for the discovery of witches, but to locate water, oil or precious minerals. Others see the origin of the name in the once considered mysterious bombardment of seeds from the persistent fruits. When the yellow pennants of the witch hazel are uncoiled and the November woods are tinged with a yellow halo

by the millions of crinkly petals, last seasons woody capsules are opened and loaded and ready to bombard the loiterer in the woods with their doubled barrelled load of hard bony seeds. With the contraction of the walls of the capsule in drying the seeds are suddenly and forcibly expelled a distance of a score of feet or more.

There are three existing species of witch hazel and their distribution confirms the story learned from that of the sweet gum. Our North American form ranges from the maritime provinces of Canada westward up the St. Lawrence valley through southern Ontario to Wisconsin and eastern Nebraska, and southward to northern Florida and eastern Texas. It thus extends much farther north than the sweet gum and unlike the latter it reaches its largest size on the slopes of the higher Alleghanies in the Carolinas. The wood is too small to be of any particular use. The witch hazel is, however, often cultivated as an ornamental plant in our northern states and in northern and western Europe, because of its odd habit of blooming in the fall and winter, a habit shared by the oriental species. The bark and leaves are slightly astringent and although without any known essential properties are largely used in homoepathic practice, and the extract made by distilling the bark in dilute alcohol is extensively sold as a toilet water.

The two other existing species of witch hazel are Asiatic one, *Hammelia japonica* S. & Z. being found in the mountains of Japan (Kiusiu and Nippon) and southern China (Kiangsi and Hupeh). Thus all the witch hazels are essentially small mountain trees or shrubs and not bottom dwellers like the sweet gum.

While we are sure, from their present distribution, that the witch hazels of today are the relics of an ancient line, we know little of their geological history. In the mid-Cretaceous of North America a number of leaves have been found which have been described under the name of *Hamamelites* (Saporta). Some of these are very like witch hazel leaves but whether they are veritable witch hazels or represent some other members of this family it is impossible to determine conclusively. Other related forms occur in the early Eocene of Belgium, France and Montana. A

petrified wood that is closely related to if it is not true witch hazel wood (*Hamamelidoxylon*) has been described from the mid-Cretaceous of France and flowers (*Hamamelidanthium*) are preserved in the Baltic amber (Lower Oligocene). Finally unmistakable witch hazel leaves occur in the Pliocene of the Auvergne (Cantal) so that we know that the witch hazel was present in Europe in pre-glacial times although it became entirely extinct on that continent during the period of glaciation.

SHORE VEGETATION OF FLATHEAD LAKE, MONTANA

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The plant life found on the beach of a large body of water between the lines of high and low water forms a very distinct plant association. It varies little for long periods of time, and yet is only a stage in the development of the vegetation. It consists of plants that are able to survive under adverse conditions; such as extreme drought, submersion, action of winds and waves, and the scraping of ice, logs and floating debris at times of high water.

The difference in level of Flathead Lake, Montana, at times of high and low water is very great. In 1916 the high water mark was reached on July 4. It lacked about four feet of the high water mark of 1894. The total rise from June 16 to July 4 was 60.5 inches. The water began to fall on July 5 varying from 1 to 5 inches a day. On August 3, there had been a total fall of 89 inches. For the entire season the difference between high and low water mark was 160 inches.

From the record of this season it can be seen that the shore plants had no chance to begin growing until midsummer. Some were killed from remaining too long under water. Every high-water year many acres of low-lying meadow and swamp-thicket are submerged.

The shore successions are of both xerophytic and hydrophytic types, the same kind of climax forest results from either. Where there is not enough moisture for a forest, a prairie formation is developed, as on the south and west sides of the lake and part of Wild Horse Island.

The altitude of Flathead Lake is 2916 feet; the plant life is that of the Transition Zone. The prevailing type of forest is the Douglas fir –western larch forest. Beside these dominant

Fig. 1. A portion of the swamp at the lower end of Flathead Lake. The water here is very shallow, becoming shallower in the distance, until it terminates in a mud flat and extensive meadow. In high water this portion of the lake is from ten to seventeen feet deeper than shown in the picture. (Photograph by Elrod.)

Fig. 2. Gravel beach east of the Biological Station, showing sand-bar willow and dogwood. Douglas fir and larch forest in the background. This beach is submerged early in the season. (Photograph by Elrod.)

trees, there are several others; yellow pine, lowland fir, birches, cottonwood, hawthorne, maple, alder, and juniper. The islands are covered with the same kind of forest.

In some places the forest reaches to the very edge of the rock cliffs which rise abruptly from the water of the lake; between the rocky points, some of the bays are filled with extensive swamp meadows. East of Polson at the south end of the lake is a large swamp. At the head of the lake the delta of the Flathead River extends for a long distance and here there are sandy beaches. The swamps merge into meadows, and are backed by swamp thickets of alder, dogwood, birch and willows. With these exceptions the stony beach is practically continuous around Flathead Lake and around the islands.

The successions of shore vegetation may be classed as follows:

Xerophytic. A, The rock shore succession; B, the stony beach succession.

Hydrophytic. A, The swamp meadow succession; B, the delta swamp succession.

All these successions result finally in the climax forest and the transitional stages can be traced.

A. The rock shore succession

The first plants to appear upon the rocks are the lichens. The crevice plants are next to appear, followed by mosses and ferns. If the rocks are at a steep angle and exposed to wind and waves the development is very slow. One of the most interesting of crevice plants is a little blue violet seen in the cracks of the bare rocks at Idlewilde and some of the other islands. It also grows among the stones on the beach. The Jacob's ladder is a conspicuous rock plant and with it grows a small hairy mustard, *Arabis hirsuta*, and the brittle fern, *Cystopteris fragilis*. When a certain amount of soil has been formed the kinnikinnick takes possession and forms a solid heath mat. This is followed by various woody shrubs; roses, gooseberries, currants, ninebark, and buffalo berry. As the forest plants increase tree growth begins.

The crevice plants common along the shores of the lake are:

Polemonimum humile R & S.
Arabis hirsuta.
Artemisia discolor Dougl.
Cerastium alpinum L.
Sedum stenopetalum Pursh.
Heuchera cylindrica var. *glabella* T. & G. = H. glabella.
Viola adunca Smith.
Geum triflorum Pursh.
Erigeron speciosus DC.
Pentstemon spp.
Aster spp.

Arctostaphylos uva-ursi L. is the most important plant in forming the heath mat and holding moisture. *Berberis repens* Lindl. soon gets a foothold. These two are also pioneer plants in the stony beach succession. The shrubs are also much the same in both successions. The common shrubs are:

Shepherdia canadensis (L) Nutt.
Opulaster opulifolius var. *pauciflorus* T. & G.
Symphoricarpos occidentalis Hook.
Acer glabrum Torr.
Amelanchier alnifolia (Nutt) T. &. G.
Philadelphus lewisii Pursh.
Betula occidentalis Hook. On the beach.
Alnus tenuifolia Nutt.
Prunus demissa Nutt.
Cornus stolonifera Michx.
Symphoricarpos racemosus Michx.
Holodiscus ariaefolia. (Smith) Green.
Ribes saxosum Lindl.
Ribes irriguum Dougl.
Ribes cereum Dougl.
Rosa nutkana Presl.
Rosa pisocarpa Gray.

B. The stony beach succession

The beach is composed of rounded water-worn rocks of all sizes from large boulders to the small pebbles of the gravel beaches. Between these stones many plants find a foothold and some large trees.

The beach trees are:

Populus trichocarpa (Hook) T. & G.
Crataegus douglasii Lindl.
Alnus tenuifolia (L) Nutt.
Cornus stolonifera Michx.
Betula occidentalis Hook.
Betula alba L.
Salix lasiandra Beuth.
Salix fluviatilis Nutt.
Pinus ponderosa Dougl.
Juniperus virginiana L.

The juniper, commonly called red cedar, is the most characteristic tree of the Flathead Lake shore, growing on all the islands. Some of the old trees are making a hard struggle for life. Their crooked branches have been beaten by the storms of many winters and their roots have been exposed by the scraping of ice and logs. There are large yellow pines growing on the beach in many places. It seems reasonable to suppose that these trees are survivals of a time when the present shore was above high water mark. It would be impossible for seedlings of either pine or juniper to get a start under present beach conditions. This may be due to climatic changes affecting the precipitation of the region. The climax forest has advanced to its limit of extension under the present conditions. The pioneer plants of the stony beach succession are much the same as in the rock shore succession. The shrubs are also the same. *Rhus toxicodendron* L. is common, spreading over the stony beaches and back into the woods. *Oenothera biennis* L. and *Asclepias speciosa* Torr. have made their appearance on the shores and now seem quite at home. *Helenium autumnale* L. is one of the showiest of the beach plants. The purple spikes of the false dragon head, *Physostegia parviflora*, contrast well with the yellow wheels of *Steironema ciliatum*.

The following plants were noted on the beach at Safety Bay on August 7:

Erigeron speciosus DC.
Pentstemon acuminatus Dougl.
Balsamorrhiza saggittata Nutt.
Lupinus ornatus Dougl.
Chrysopsis villosa (Pursh) Nutt.

Allium cernuum Roth.
Galium boreale L.
Vicia americana Muhl.
Aster laevis L.
Castilleja miniata Dougl.
Glycyrrhiza lepidota Nutt.
Anaphalis margaritacea Gray.
Monarda menthæfolia Graham.
Sisymbrium incisum Eng.
Campanula rotundifolia L.
Calochortus apiculatus Baker. (Dried seed pod.)
Cymopterus longipes Wats.
Fritillaria pudica Spreng. (Dried seed pod.)
Apocynum androsaemifolium L.
Epilobium adenocaulon Haussk.
Lithospermum ruderale Dougl.
Rumex persicarioides L.
Gaillardia aristata Pursh.
Artemisia discolor Dougl.
Aster occidentalis Nutt.
Viola adunca Smith.
Epilobium spicatum Rydb.
Arctostaphylos uva-ursi (L.) Spreng.
Berberis repens Lindl.
Mentha arvensis var. *glabrata* Bth.
Solidago occidentalis (Nutt.) T. & G.
Prunella vulgaris L.
Spiræa lucida Dougl.

At Yellow Bay most of the plants in the preceding list are found. Poison ivy covers a portion of the beach near the point. Equisetum, speedwell, spring cress, Canada mint and buttercups, steironema and yellow monkey flower appear on the small mud flats as the water goes down. *Ranunculus flammula* var. *intermedius* is a slender little buttercup growing nearly everywhere along the shores of the lake.

Salix fluviatilis Nutt. is the first shrub to appear on the sand bars and muddy banks. In such places are found:

Mimulus langsdorfii Donn.
Ranunculus douglasii Howell.
Ranunculus acriformis Gray.
Halerpestes cymbalaria Pursh.
Veronica serpyllifolia L.
Veronica scutellata L.
Veronica peregrina L.

Sagittaria arifolia Nutt. covers the mud flats at the mouth of Swan River. At Lakin's Point was found *Dodecatheon meadia* var. *pauciflorum* and *Spiranthes romanzoffiana*. On the shore of the river below the old club house *Isoetes Howellii* was fairly abundant.

A. Swamp meadow succession

The swamps and meadows at the head of the lake, in the bays on the west side, and at the foot of the lake, include very many plants of the foregoing lists. The meadows are submerged at high water and in addition to the meadow grasses have several species of swamp grasses, rushes and sedges.

On August 7 the following were noted in the swamp west of the islands:

Carex vesicaria L.
Juncus balticus Willd.
Eleocharis palustris (L) R & S.
Glyceria sp.
Scirpus lacustris L.
Cardamine spp.
Ilysanthes dubia (L.) Barnhart.
Mimulus langsdorfii Donn.
Ranunculus unalaschensis Bess.

Here there were large trees of quaking asp and the willows formed clumps on the north side of the meadow. The common willows are:

Salix scouleriana Barratt.
Salix lasiandra Beuth.
Salix cordata var. *mackenziana* Barratt.
Salix rostrata Rich.
Salix fluviatilis Nutt.

These swamp plants were found near the mouth of Swan River.

Sium cicutaefolium Gmel.
Alisma plantago L.
Sagittaria arifolia Nutt.
Equisetum fluviatile L.
Sparganium androcladum Eng.
Triglochin maritima L.
Scutellaria galericulata L.

Myriophyllum verticillatum L.
Ranunculus aquatilis var. *capillaceus*.
Ranunculus aquatilis var. *caespitosus*.
Menthe canadensis L.

Lysichiton kamtschatcensis Schott. grows in the dark willow thicket at the back of the swamp.

At Polson swamp were noted:

Potentilla palustris L. Scop.
Menyanthes trifoliata L.
Acorus calamus L.
Allium schoenoprasum Wats.
Gratiola virginiana Benth.
Typha latifolia L.
Hypericum canadense var. *boreale* Britton.
Carex conjuncta Boott.
Juncus acuminatus Mx.
Scirpus microcarpus Presl.
Juncus balticus var. *littoralis* Eng.
Hippuris vulgaris L.

B. The delta swamp succession

Where the Flathead River enters the lake it has formed a long delta of sand and river silt. For a little distance the sandy points are destitute of vegetation, then the sandbar willow, *Salix fluviatilis* appears. The pioneer plants on the delta sand are about the same as those found on the stony beaches; when a layer of soil has been formed the shrubs come in, such as service-berry, choke-cherry, roses, ninebark and willows of several kinds. Where the delta is high enough there is a good growth of cottonwood, hawthorne, quaking asp and birch. From the mountain top the delta looks like a long tongue of trees reaching out into the lake. It furnishes an excellent example of the filling-in process.

Salt Lake City, Utah.

BOOKS AND CURRENT LITERATURE

CONDITIONS AFFECTING THE POTENTIALITY OF THE SEED.—Kidd and West have written a series of thoughtfully critical papers[1] which have placed all botanists under obligations to them for another piquant discussion of fundamental importance. It is gratifying to note the increase in such resume's which have come in recent years from the pens of our British colleagues. Their disussions are singularly refreshing because they deal with fundamental questions instead of the unessential, though less difficult questions usually studied.

An apt quotation will illustrate this point. "A few fundamental principles are necessary for the study of growth and development. These are conspicuous by their absence in existing text-books of plant physiology, which excel in the assemblage of interesting curiosities and of uncorrelated details. The phenomena of *normal growth* seem to call for further study and for the application of mathematical treatment. Even a clear grasp of the general conception of the compound interest law of development, at once greatly simplifies the handling of problems of physiological predetermination and of growth."

The main part of their discussion deals with the published results of other workers, and upwards of 200 titles are found in their bibliography. Their own experimental work is only what seemed necessary to fill the most serious gaps. The aims of the writers are clearly stated in their opening sentences. "In a survey of the literature of the last fifty years dealing with the seed it is interesting to note that attention has been almost entirely concentrated upon the question of germination. The effect upon germination of every manner of treatment and of every sort of condition has been investigated in the case of the seeds of a great range of cultivated and wild plants."

"In only a very few cases has attention been directed upon the question suggested by the title of this paper, namely, as to how far the physiological condition of the plant in the seed-stage (i.e., in mat-

[1] Kidd, F. and West, C. Physiological predetermination: the influence of the physiological condition of the seed upon the course of subsequent growth and upon the yield. Annals of Appl. Biol., **5**: 1–10; 112–142; 157–170; 220–251. 1918–1919. **6**: 1–26. 1919.

uration, dormancy, and germination) may exert a predetermining influence upon the whole subsequent course of growth and development. It is obvious from the point of view of crop production that this question as to the equality and size of the plants *produced from any sample* of seed may be even more important than the question as to what percentage of the seed is capable of germination."

The problem as outlined and discussed here is seen to be one of great scientific and economic importance.

Soaking seeds in water for periods varying from 6 to 24 hours was shown to have profoundly harmful effects upon the subsequent growth of certain plants. Differences existed which would often vitiate the results of an experiment.

The effect of parental conditions, of harvesting conditions, and of conditions during the germination and seedling stages of the plant are critically discussed. The importance of the "compound interest" law as a means of expressing the growth of a plant is pointed out. It appears that there are two main factors determining the final yield (a) the initial "capital," and (b) the "rate of interest." The first of these is a great predetermining factor and is not modified by subsequent environmental conditions, but the other factor may be somewhat affected by such conditions.

The selection of vigorous seedlings is matter of common practice yet little is known whether the vigor of the seedling is correlated with a vigorous adult. "The critical question is therefore—Can we propound a law to the effect that increased vigor of seedling development due to environmental conditions as distinct from hereditary causes, is correlated with increased vigor of growth throughout the life of the plant and with increased yield independently of the subsequent environmental conditions?

These and other questions are discussed in a spirit which cannot fail to be stimulating to all further work in this important field.—H. S. Reed.

The Cycads. Recently another addition has been made to the University of Chicago Science Series under the title The Living Cycads.[1] The text is divided into three parts. Part I gives the distribution of the living cycads, and is made very interesting reading by the inclu-

[1] Chamberlain, Charles J. The Living Cycads. University of Chicago Press, 1919 ($1.50).

sion of many general observations incident to the extensive investigations of the author in Mexico, Australia, New Zealand and Africa; Part II describes the life history of the cycads, and Part III treats the phylogeny and evolution of the group. The language used, even in the chapters dealing with the life history, is so clear and simple that the average educated person can grasp it. Nearly one hundred well-chosen photographs and drawings serve to elucidate the text. The publication is to be followed by a more extensive account of the author's research on the morphology of the cycads.—J. G. Brown.

NOTES AND COMMENT

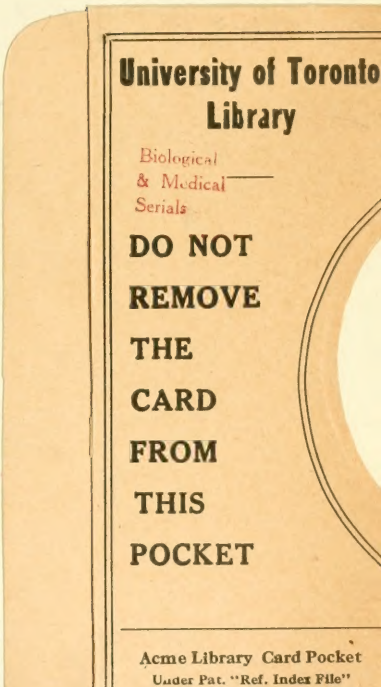
With this issue THE PLANT WORLD ceases to appear under its present name and management. The subscription list and good will of the journal have been transferred to the Ecological Society of America, and it will continue to appear as a quarterly under the title *Ecology*. The number of pages published per annum in quarterly form will be as great as heretofore under monthly appearance. As the Editorial Board of the Ecological Society aims to use the new journal as a reflection of the science of ecology in its broadest aspects, the readers of THE PLANT WORLD may expect to find in *Ecology* papers covering all phases of the ecology and physiology of plants, as well as the added feature of papers dealing with animal ecology.

The desirability of the publication of a journal by the Ecological Society led to the suggestion that THE PLANT WORLD be made the organ of the Society. Under its present name, however, it was impossible to indicate the including of animal ecology in its scope. Since it was necessary to change the name of the journal it was obviously desirable to start with a new series of volume numbers. In spite of these rather profound outward changes it is hoped that the many friends of THE PLANT WORLD will look upon the new journal as a continuation of the old one, now enjoying the support of a well established society and deriving its papers from a larger circle of workers.

It has been arranged that all subscribers who have paid in advance for 1920, or any part of the year, will receive *Ecology*. If there should be any persons to whom this arrangement is not acceptable, they should notify Dr. C. Stuart Gager, Business Manager, Brooklyn Botanic Garden, Brooklyn, N. Y.

The members of the Plant World Association who have been financially interested in the journal will continue their organization under the name The Plant World Company. All requests for volumes and single numbers of THE PLANT WORLD should be addressed to The Plant World Company, Tucson, Arizona. Regarding the future handling of the line of scientific apparatus, books, separates and other publications which have been sold by THE PLANT WORLD, readers are referred to an announcement in the advertising pages of this issue.

J. Smeaton Chase's recently issued book, California Desert Trails (Houghton, Mifflin Company), is not a scientific treatise,—in fact the author expressly disclaims the title of botanist, or even the more indefinite one of naturalist. Nevertheless the professional student will find in it much valuable information concerning the ecology and floristics of this interesting region, presented in untechnical language, but giving evidence of careful observation and happily without falling into the slips which render some books of this class distasteful to scientific readers. The author has not only a quick sympathy for the varied aspects of the desert, but he sees them with an accurate discernment and portrays them faithfully and with a delightful literary skill. His pages reflect the illusive but compelling charm which the desert holds for those who are intimate with its austere beauty. We commend them to any who wish to form, or to recall, a picture of the California desert and its inhabitants as nature forms them. The full-page illustrations, of which there are 32, graphically representing desert scenery and plants, add to the interest of the text, and a descriptive appendix will enable nature students to determine many of the commoner species.—S. B. Parish.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